SOLARTRON D.V.M.

LM1604 D.C.

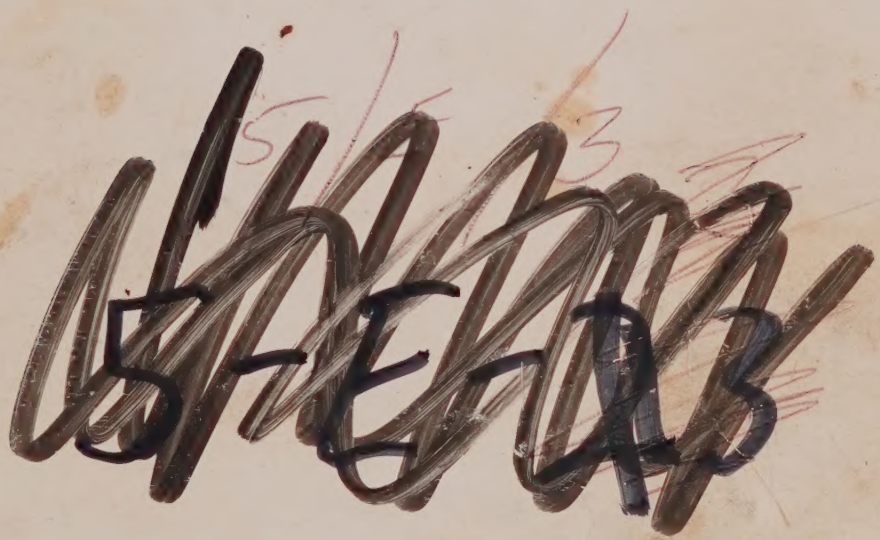
LM1604/05 AC/DC

C6-54-098

DIGITAL VOLTMETER
LM 1604 DC ONLY
LM 1604/05 DC & AC

AND

FAN OUT UNITS EX3052 & EX3054
AUTO-RANGE BOARD EX3055



SOLARTRON

TECHNICAL MANUAL

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DIGITAL VOLTMETER
LM1604 DC ONLY
LM1604/05 DC & AC

AND

FAN OUT UNITS EX3052 & EX3054
AUTO RANGE BOARD EX3055

Part No: 16040103

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THE SOLARTRON ELECTRONIC GROUP LTD

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1604/2/1070

CONTENTS

		Page
SECTION 1	GENERAL	1.1
	Specification	1.1
	Ranges	1.1
	Short Term Accuracy	1.1
	Long Term Accuracy	1.2
	Temperature Effects	1.3
	Input Characteristics	1.4
	Interference Rejection - Series Mode	1.5
	Interference Rejection - Common Mode	1.6
	Temperature Range	1.6
	Mains Supply	1.6
	Fan Out Unit EX3052	1.6
	Fan Out Unit EX3054	1.7
	Dimensions	1.7
	Weight	1.7
	Accessories	1.7
	Ordering Detail	1.7
SECTION 2	OPERATION	2.1
	General	2.1
	Preliminary Adjustments	2.1
	Front Panel Controls	2.2
	Rear Panel Controls	2.3
	Calibration	2.3
	DC Voltage Measurement	2.4
	AC Voltage Measurement	2.5
	Interference Rejection	2.6
	DC Measurements	2.6
	Two Terminal Measurements	2.6
	Three Terminal Measurements	2.6
SECTION 3	TECHNICAL DESCRIPTION	3.1
	Basic Concept	3.1
	General Principles of Dual Ramp Voltmeters	3.1
	Principles of the LM1604 Dual Ramp Voltmeter	3.2
	Sequence of Operation	3.2
	Power Supplies	3.3
	Interference Rejection	3.3
	Power Supplies	3.4
	Mains Input	3.4
	Earthy Supplies	3.4
	Floating Supplies	3.4
	Range Switching and Mode Selection	3.6
	General	3.6
	V or mV Indication	3.6
	DC Mode	3.6
	Relay Switching	3.6
	10mV Range	3.6
	100mV Range	3.6
	1V Range	3.6
	10V Range	3.6
	100V Range	3.6
	1000V Range	3.6
	Remote Mode	3.7

AC Mode	3.7
Auto Mode	3.7
Input Amplifier Switching	3.8
General	3.8
10V Range	3.8
10mV Range	3.8
100mV and 1V Ranges	3.8
100V Range	3.8
1000V Range	3.8
Thermal emf Compensation	3.8
DC Filters	3.9
General	3.9
Out	3.9
μV Noise	3.9
40dB	3.9
Cal	3.9
μV Zero	3.9
Floating Power Supply	3.9
Inverter	3.10
Chopper AC Supplies	3.10
6kHz Multivibrator	3.10
5MHz Oscillator	3.10
Input Amplifier	3.12
General	3.12
Chopper	3.12
DC Offset	3.12
Temperature Compensation	3.12
Spike Reduction	3.12
Chopper Channel Pre-Amplifier	3.13
Chopper Channel Output Stage	3.13
Current Zero	3.13
AC Pre-Amplifier	3.13
Mixer	3.13
Output Stage	3.13
Overload Protection	3.13
Logic Conventions	3.14
Integrator and Reference Supply	3.14
Reference Supply	3.14
General	3.14
Constant Current Supply	3.14
Thermal Feedback Amplifier	3.14
Integrator	3.14
General	3.14
Ramp Up	3.14
Delay	3.15
Ramp Down	3.16
Drift Correct	3.16
Floating Logic	3.18
General	3.18
2MHz Clock Oscillator	3.18
2MHz Gate	3.18
50Hz Squarer	3.18
25Hz Bistable	3.18
Ramp Up Bistable	3.18
Delay Monostable	3.18
Ramp Down Bistable	3.19
Polarity Decisions	3.19
Termination of Ramp Down	3.19
Drift Correct	3.19
Clock Frequency Adjustment	3.20

Polarity and Reset Pulses 3.20
Earthy Logic 3.22
Slave Ramp Up Bistable 3.22
Display Polarity Decisions 3.22
General 3.22
Positive Polarity 3.22
Negative Polarity 3.23
AC Operation 3.23
Display Counter Reset Pulses 3.24
Staticising 3.24
General 3.24
25/s Mode 3.25
Manual Sample Mode 3.25
Remote Sample 3.25
Print Command Signals 3.25
Manual Sample 3.25
10000 Indication 3.26
19999 Pulse and Overload Indication 3.26
Display and Counters 3.27
General 3.27
Binary Counter 3.27
Staticised Store 3.28
Binary to Decimal Decode 3.28
9999 Gate 3.29
Staticised Outputs 3.29
Logic Levels 3.31
Measurement of AC 3.32
Introduction 3.32
Principles of Operation 3.32
Range Switching and Mode Selection 3.32
General 3.32
DC Mode 3.32
AC Mode 3.32
100mV Range 3.32
1V Range 3.33
10V Range 3.33
100V Range 3.33
750V Range 3.33
AC Amplifier Switching 3.33
1V Range 3.33
100mV Range 3.33
10V Range 3.34
100V Range 3.34
750V Range 3.34
Input Attenuator 3.34
AC Amplifier 3.34
Overload Protection 3.34
Frequency Response 3.34
Input Stage 3.34
Intermediate Amplifier 3.34
Output Stage 3.34
Demodulator 3.35
Filter 3.35
General 3.35
Slow 3.35
Medium 3.35
Fast 3.35
EX3055 Auto Range Board 3.36
Introduction 3.36
Caution 1 3.36

Caution 2 3.36
Range Decisions 3.36
Auxiliary Bistable 3.37
Inhibit Hold 3.37
Auto Range/Manual Operation 3.37
Circuit Description 3.37
Range Change Decisions 3.37
19000 Gating 3.37
1800 Gating 3.37
Auxiliary Bistable 3.38
Range Counter 3.39
General 3.39
No Range Change Required 3.39
Down Range Decision 3.39
Up Range Decision 3.40
Auto/Manual Decision 3.40
General 3.40
Manual Range Changing 3.40
Auto Range Change 3.40
Counter Decoding 3.40
100V Range 3.40
10V Range 3.40
1V Range 3.40
100mV Range 3.40
10mV Range 3.40
Inhibit Hold and Print Commands 3.40
Fan Out Units 3.42
General 3.42
Positive Logic Fan Out Unit EX3054 3.42
Introduction 3.42
Board 1 3.42
Counter Outputs 3.42
Print Command 3.42
Digitise Command 3.42
Contact Sample 3.42
Gated Clock 3.42
Direct Polarity 3.42
Staticised Polarity 3.42
Ramp Up 3.42
Board 2 3.42
AC Sub Unit Command 3.42
BCD Range Commands 3.43
Binary to Decimal Decode 3.43
Range Selection 3.44
Auto Ranging 3.44
Negative Logic Fan Out Unit EX3052 3.46
Introduction 3.46
Board 1 3.46
Counter Outputs 3.46
Print Command 3.46
Digitise Command 3.46
Contact Sample 3.46
Gated Clock 3.46
Direct Polarity 3.46
Staticised Polarity 3.46
Ramp Up 3.46
Board 2 3.46
AC Sub Unit Command 3.46
BCD Range Commands 3.46
Binary to Decimal Decode Command Failure 3.47

BCD Range Outputs 3.47
Special Auto Range Command 3.48

SECTION 4 **SERVICING** 4.1
Introduction 4.1
Recommended Tools 4.1
Dismantling Instructions 4.2
Removal of the Floating Section 4.2
Access to Mother Board and Plug PLD 4.3
Removal of Boards 1, 3, 5 and 10 4.3
Removal of Board 13 4.4
Removal of Board 6 4.5
Removal of Board 9 4.5
Removal of Board 8 4.5
Removal of Board 4 4.5
Replacement of Range Relays 4.5
Removal of Standard Cell 4.5
Access to Range Switches and Input Terminals 4.5
Access to MODE Switches 4.5
Access to DC FILTERS and CAL Switches 4.6
Access to AC RESPONSE and μV ZERO Switches 4.6
Refitting of Boards 4.6
Removal of Instrument Case 4.6
Removal of Board 20 4.7
Access to Board 21 4.7
Removal of Board 2 4.7
Removal of Board 22 4.7
Refitting of Boards 4.7
Replacement of V/mV Neons 4.7
Replacement of ± and ~ Neons 4.7
Replacement of Display Tubes 4.8
Replacement of Decimal Point Neons 4.8
Replacement of the Overload Neon 4.8
Access to Front Panel Controls 4.8
Fitting of Optional Kits 4.8
EX3055 Auto Range Board 4.8
EX1605 AC Unit 4.9
EX3052 and EX3054 Fan Out Units 4.10
Dismantling of Fan Out Units 4.11
LM1604 Voltmeter Test Procedure 4.12
Recommended Test Equipment 4.12
Detailed Tests 4.12
Preliminary 4.12
Rail Voltage 4.12
Inverter Frequency 4.12
Oven Temperature 4.12
20 Volt Zero 4.12
Positive/Negative Error 4.12
Chopper Spikes 4.12
Temperature Compensation Circuit 4.13
Voltage Zero 4.13
Current Zero 4.13
Voltage Zero Error 4.13
Zener Calibration 4.13
Clock Adjustment 4.13
Decimal Point Position and Annunciators 4.13
Input Impedance 4.13
Series Mode Rejection 4.13
AC Common Mode Rejection 4.14

DC Common Mode Rejection 4.14
Low to Guard Insulation 4.14
Overload Current 4.14
Remote Ranging 4.14
Floating Box Capacitance 4.14
Range Calibration 4.15
10V 4.15
10mV 4.15
100mV 4.15
1V 4.15
100V 4.15
1000V 4.15
Linearity 4.15
Temperature Tests and Set Up 4.15
Final Calibration 4.15
Modification for 60Hz Operation 4.16
EX1605 AC Unit Test Procedure 4.16
Recommended Test Equipment 4.16
Detailed Tests 4.16
Isolation and Short Circuit Checks 4.17
Zero Checks 4.17
1V Range Calibration 4.17
Linearity 4.17
100V Range Calibration LF 4.18
750V LF 4.18
750V HF 4.18
10V 4.18
100mV 4.18
Frequency Response 1V Range 4.18
100V Range Calibration HF 4.18
Frequency Response 10V Range 4.18
Frequency Response 100V Range 4.19
Frequency Response 750V Range 4.19
Overload Recovery 4.19
Step Response 4.19
1s 4.19
3s 4.19
10s 4.19
Range Change 4.19
Crest Factor 4.19
Common Mode Rejection Ratio 4.20
EX3055 Test Procedure 4.20
Recommended Test Equipment 4.20
Detailed Tests 4.20
LM1604 Performance Check 4.20
Auto Range Interference 4.20
Range Change Points 4.20
Range Selection 4.20
Delay Monostable Operation 4.20
Manual Sampling with Auto-Range 4.21
Print Command 4.21
EX3054 Test Procedure 4.22
Recommended Test Equipment 4.22
Detailed Tests 4.22
BCD 7_0 4.22
BCD 8_0 4.22
BCD 7_1 4.22
BCD 8_1 4.22
BCD 7_2 4.22
BCD 8_2 4.22

BCD 7_3 4.22
BCD 8_3 4.22
BCD 0_4 4.22
BCD 1_4 4.22
Polarity 4.23
Range Output 4.23
Remote Range 4.23
Remote Mode 4.23
Logic Outputs 4.23
Digitise Command 4.23
EX3052 Test Procedure 4.24
Recommended Test Equipment 4.24
Detailed Tests 4.24
$BCD7_0$ 4.24
$BCD8_0$ 4.24
$BCD7_1$ 4.24
$BCD8_1$ 4.24
$BCD7_2$ 4.24
$BCD8_2$ 4.24
$BCD7_3$ 4.24
$BCD8_3$ 4.24
$BCD0_4$ 4.24
$BCD1_4$ 4.24
Polarity 4.25
Range Output 4.25
Remote Range 4.25
Mode Output 4.25
Remote Autorange 4.25
Special Autorange 4.25
Remote Mode 4.25
Logic Outputs 4.25
Digitise Command 4.26
Power Supply 4.26
Limited BCD Outputs 4.26

ILLUSTRATIONS

Figure		Page
1.1	Typical AC Accuracy	1.2
1.2	Internal Reference Cell-Temperature Characteristics	1.3
1.3	μV Noise Filter	1.5
1.4	40dB Filter	1.5
2.1	Preliminary Adjustments	2.1
2.2	Front Panel Controls	2.2
2.3	Rear Panel Controls	2.3
2.4	Calibration	2.3
2.5	DC Voltage Measurement	2.4
2.6	AC Voltage Measurement	2.5
2.7	Two Terminal Measurements	2.6
2.8	Three Terminal Measurements	2.6
3.1	Basic Principle	3.1
3.2	Basic Dual Ramp Block Diagram	3.1
3.3	Interference Rejection - Isolation from Earth	3.3
3.4	Timing Diagram - Principal Waveforms	3.3
3.5	Block Diagram - Complete Voltmeter	3.3
3.6	Input Amplifier - 10V Range	3.8
3.7	Input Amplifier - 10mV Range	3.8
3.8	Input Amplifier - Block Diagram	3.12
3.9	Input Amplifier - Frequency Response	3.12

3.10	Spike Reduction - Chopper Bridge Circuit	3.13
3.11	Detector Output - Positive Ramp Up	3.15
3.12	Detector Output - Negative Ramp Up	3.15
3.13	Integrator Waveform with 50Hz Interference	3.15
3.14	Drift Correct Waveform	3.20
3.15	Clock Frequency Adjustment	3.20
3.16	Polarity and Reset Pulse - Negative Polarity	3.21
3.17	Polarity and Reset Pulse - Positive Polarity	3.21
3.18	Slave Ramp Up Bistable Operation	3.22
3.19	IC2d Operation - Positive Polarity	3.22
3.20	Polarity Bistable Operation - Positive Polarity	3.23
3.21	IC2d Operation - Negative Polarity	3.23
3.22	Polarity Bistable Operation - Negative Polarity	3.23
3.23	Reset Pulses - Negative Polarity Input	3.24
3.24	Reset Pulses - Positive Polarity Input	3.24
3.25	Staticise Pulses	3.25
3.26	Print Command - Manual Sample Mode	3.26
3.27	19999 Pulse and Overload Indication	3.26
3.28	Display and Counters - Block Diagram	3.27
3.29	Measurement of AC	3.32
3.30	Basic Principle	3.32
3.31	AC Amplifier - 1V Range	3.33
3.32	AC Amplifier - 100mV Range	3.33
3.33	AC Amplifier - 10V Range	3.34
3.34	AC Response - 10s	3.35
3.35	AC Response - 3s	3.35
3.36	AC Response - 1s	3.3·
3.37	EX3055 Block Diagram	3.36
3.38	Detect 19000 Gate	3.37
3.39	Detect 1800 Gate	3.38
3.40	Auxiliary Bistable Operation	3.38
3.41	Range Gates Operation	3.39
4.1	LM1604 Dismantled for Servicing	4.1
4.2	Removal of Floating Section	4.2
4.3	Removal of Board 5 and 10	4.3
4.4	Removal of 'Disconnect' Terminals	4.4
4.5	Access to Board 13	4.4
4.6	Component Location - Floating Section	4.5
4.7	Removal of Instrument Case	4.6
4.8	Board Location - Display Section	4.7
4.9	Fitting the EX3055 Auto Range Board	4.8
4.10	Fitting the EX1605 AC Kit	4.9
4.11	Fitting a Fan Out Unit	4.10
4.12	Fan Out Unit - Physical Construction	4.11
4.13	EX1605 Dummy Load Circuit	4.12
4.14	Chopper Spikes - Optimum Adjustment	4.13
4.15	Measurement of Input Impedance	4.13
4.16	Measurement of Series Mode Rejection	4.14
4.17	Measurement of AC Common Mode Rejection	4.14
4.18	Measurement of DC Common Mode Rejection	4.14
4.19	Measurement of Low/Guard Insulation	4.14
4.20	LM1604/Kienzle Printer Interface Circuit	4.16
4.21	VT3 Collector Waveform	4.20
4.22	Print Command Signal	4.21
4.23	Print Command Delay	4.21
4.24	EX3054 Logic Output	4.23
4.25	EX3052 Logic Outputs	4.25

TABLES

Table		
3.1	DC Ranging	3.7
3.2	Binary Counter Truth Table	3.27
3.3	Binary to Decimal Decode	3.28
3.4	Socket SKB Pin Connections	3.30
3.5	AC Ranging	3.33
3.6	Range Counter Code	3.39
3.7	BCD - Decimal Decode	3.43
3.8	EX3054 SKA Connections	3.44
3.9	Ranging Code	3.47
3.10	Range Output Code	3.48
3.11	EX3052 SKA Connections	3.49
4.1	LM1604 Rail Voltages	4.12
4.2	LM1604 Final Calibration	4.15
4.3	LM1604/Kienzle Printer Interconnections	4.16
4.4	EX1605 Linearity - 1V Range	4.17
4.5	EX1605 Linearity - 100mV Range	4.18
4.6	EX1605 Frequency Response - 1V Range	4.18
4.7	EX1605 Frequency Response - 10V Range	4.18
4.8	EX1605 Frequency Response - 100V Range	4.19
4.9	EX1605 Frequency Response - 750V Range	4.19
4.10	Accuracy of Auto Range Readings	4.20
4.11	Manual Sampling Accuracy	4.21

CIRCUIT DIAGRAMS

	Page
Power Supply and Annunciators, Board Nos 6, 21 and 22	3.5
Earthy Wiring - Range and Mode Switching, Board Nos 8 and 9	3.7
Floating Box, Board Nos 4, 6 and 7	3.9
Chopper AC Supplies and Inverter, Board No. 5	3.11
Input Amplifier and Chopper, Board Nos 10 and 13	3.13
Integrator and Reference Supply, Board No. 3	3.17
Floating Logic, Board No. 1	3.21
Earthy Logic, Board No. 2	3.27
Display Counter, Board No. 20	3.29
EX1605 AC Kit, Board Nos 1, 2 and 3	3.35
EX3055 Auto Range Board	3.41
EX3054 Fan Out Unit, Board No. 1	3.43
EX3054 Fan Out Unit, Board No. 2	3.45
EX3052 Fan Out Unit, Board No. 1	3.47
EX3052 Fan Out Unit, Board No. 2	3.49

COMPONENT PARTS LISTS AND COMPONENT LOCATION ILLUSTRATIONS

Component Parts List Abbreviations	1
1604 Assembly	2
Component Parts List for Printed Circuit Board 16049001	3
Component Location -Board 1	4
Component Parts List for Printed Circuit Board 16049003	5
Component Location - Board 3	6
Component Parts List for Printed Circuit Board 16049004	7
Component Location - Board 4	8
Component Parts List for Printed Circuit Board 16049005	9
Component Location - Board 5	10
Component Parts List for Printed Circuit Board 16049006	11
Component Location - Board 6	11

Component Parts List for Printed Circuit Board 16049007 12
Component Location - Board 7 12
Component Parts List for Printed Circuit Board 16049008 13
Component Location - Board 8 14
Component Parts List for Printed Circuit Board 16049009 15
Component Location - Board 9 16
Component Parts List for Printed Circuit Board 16049010 17
Component Location - Board 10 18
Component Parts List for Printed Circuit Board 16049013 19
Component Location - Board 13 19
AC Converter EX1605 20
Component Parts List for 1605 General Assembly 20
Component Parts List for Printed Circuit Boart 16059001 21
Component Location - Board 1 22
Component Parts List for Printed Circuit Board 16059002 23
Component Location - Board 2 24
Component Parts List for Printed Circuit Board 16059003 25
Component Location - Board 3 25
1610 Assembly 26
Component Parts List for 1610 General Assembly 26
Component Parts List for Printed Circuit Board 16109002 27
Component Location - Board 2 28
Component Parts List for Printed Circuit Board 16109006 29
Component Location - Board 6 30
Component Parts List for Printed Circuit Board 16109020 31
Component Location - Board 20 32
Component Parts List for Printed Circuit Board 16109021 33
Component Location - Board 21 34
Component Parts List for Printed Circuit Board 16109022 35
Component Location - Board 22 36
Component Parts List and Locations EX3054 36
Fan Out Unit EX3054 37
Component Parts List for 3054 Main Assembly 37
Component Parts List for Printed Circuit Board 30549001 37
Component Location - Board 1 38
Component Parts List for Printed Circuit Board 30549002 39
Component Location - Board 2 40
Auto Range Board EX3055 41
Component Parts List for Printed Circuit Board 30559001 41
Component Location - EX3055 42
Fan Out Unit EX3052 43
Component Parts List for 3052 Main Assembly 43
Component Parts List for Printed Circuit Board 30529001 43
Component Location - Board 1 44
Component Parts List for Printed Circuit Board 30529002 45
Component Location - Board 2 46

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SECTION 1
GENERAL

Dual Slope Integrating Digital Voltmeters LM1604 [d.c. only] and LM1604/05 [d.c. and a.c.] are fully programmable 0.01% accuracy instruments.

One microvolt d.c. resolution is achieved without the precautions normally necessary at such high sensitivity. Mains locked integration, coupled with excellent isolation, gives outstanding noise rejection without filters. Therefore the inherently fast measurement time is not degraded - even with maximum mains interference.

LM1604/05 provides for a.c. measurement down to 10μV while retaining 1μV d.c. capability. High input impedance and isolation from ground are maintained on both d.c. and a.c.

In auto check-out, data logging and process monitoring applications, the voltmeter is fully programmable by remote command, and d.c. auto-ranging is available. A choice of fan-out units gives the ability to communicate with systems that operate with either positive or negative logic.

SPECIFICATION

RANGES

	DC MEASUREMENT LM1604/05 ONLY				AC MEASUREMENT LM1604 & LM1604/05	
	RANGE	SENSITIVITY	FULL SCALE	INPUT R	FULL SCALE	INPUT Z
0	10mV	1μV	19.999mV	> 1 000MΩ		
1	100mV	10μV	199.99mV	>10 000MΩ	199.99mV	10MΩ 150pF
2	1V	100μV	1.9999V	>10 000MΩ	1.9999V	10MΩ 150pF
3	10V	1mV	19.999V	>10 000MΩ	19.999V	1MΩ 100pF
4	100V	10mV	199.99V	10MΩ ±½%	199.99V	1MΩ 100pF
5	1 000V	100mV	1000.0V*	10MΩ ±½%	750.0V*	1MΩ 100pF

* Range 5: Although full scale remains 1999.9V it is advisable not to exceed the value given.

Remote Range: The remote selection of any DC or AC range may be commanded via an optional Fan-out unit.

Overload: A lamp flashes when the input reaches 19999 on any range.

Auto Range: Auto is available as an optional facility and operates on all DC ranges except 5.

Scaling: On AC the instrument senses the mean value of the a.c. component of the input and displays the r.m.s. value - assuming a sine wave signal.

SHORT TERM ACCURACY

For 24 hours, at 20°C, after calibration to an external standard. Resolution and linearity errors are included

Ranges 0, 1, 2, 3, 4
±0.005% of reading ±0.005% of full scale ± zero error.

Range 5
±0.005% of reading ±0.01% of full scale.

30Hz - 5kHz All Ranges
±0.1% of reading ±0.03% of full scale

20Hz - 20kHz All Ranges
±0.2% of reading ±0.03% of full scale

20kHz - 50kHz Ranges 1 and 2
±0.5% of reading ±0.03% of full scale

20kHz - 50kHz Ranges 3, 4, 5
±0.75% of reading ±0.03% of full scale

Typical Frequency Response:
at 100kHz ±1% of reading
at 150kHz ±5% of reading

Resolution: 1 part in 20 000

1 part in 20 000

Linearity Error: <0.005% of full scale

15Hz - 5kHz ±0.005% of full scale
5kHz - 50kHz ±0.02% of full scale

Zero Error: Using external short circuit 0μV
Using μV ZERO button ±2μV

Included in the above specification provided that zero has been set with the input terminals short circuited at the voltmeter.

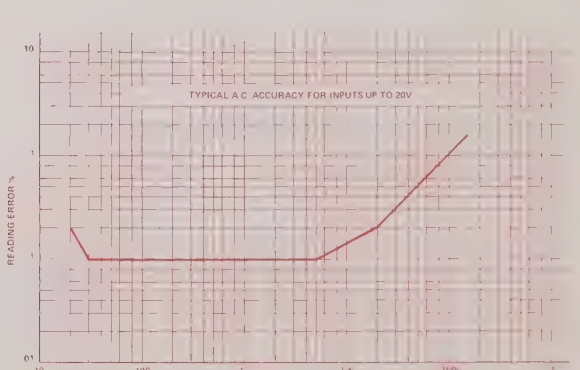


Figure 1.1 Typical a.c. Accuracy

LONG TERM ACCURACY

For 12 months, 0-45°C. Assumes zero adjustment and calibration to internal reference cell up to 30°C.

Ranges 0, 1, 2
±0.02% of reading ±0.005% of full scale ± zero error

Range 3
±0.015% of reading ±0.005% of full scale

Range 4
±0.03% of reading ±0.005% of full scale

Range 5
±0.03% of reading ±0.01% of full scale

The figures for short term accuracy are increased by

Ranges 1 and 2
±0.005% of reading

Ranges 3, 4, 5
±0.06% of reading

TEMPERATURE EFFECTS

Zero Drift 0-50°C ±0.3μV/°C

Coefficient of reading 0-50°C

Ranges 0, 1, 2, 3
±0.0005% per °C

Ranges 4 and 5
±0.001% per °C

Coefficient of Reference Cell 0-30°C
±0.0005% per °C

Ranges 1 and 2
±0.0025% per °C

Ranges 3, 4, 5

± 0.0075% per °C	20Hz to 5kHz
± 0.025% per °C	5kHz to 20kHz
± 0.04% per °C	20kHz to 100kHz

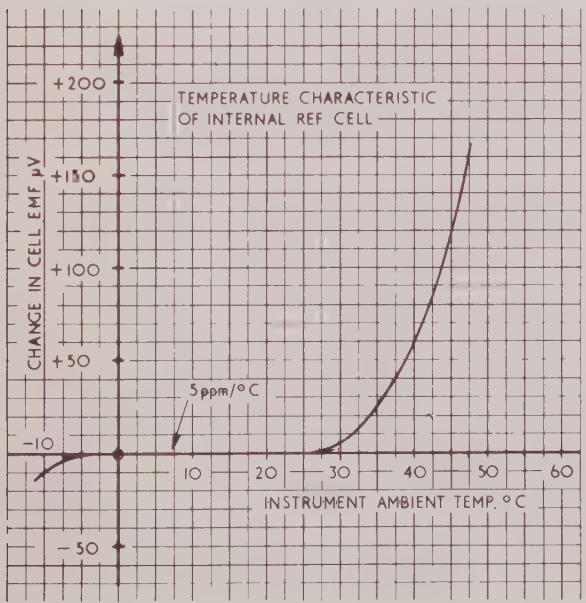


Figure 1.2 Internal Reference Cell-Temperature Characteristic

INPUT CHARACTERISTICS

Input Current

$<10^{-10}$ A

Overload

Ranges 0, 1, 2, 3

Max. permitted input	250V
Input current	<2mA

Ranges 4 and 5

Max. permitted input	1200V
Input resistance	10M $\pm\frac{1}{2}\%$

Ranges 1 and 2

Max. permitted input	250V peak
Input current	<4mA

Ranges 3, 4, 5

Max. permitted input	1100V peak

Isolation Impedance

Guard-Chassis	$>10^{10}$ Ω and <600pF	$>10^{10}$ Ω and <600pF
Low-Chassis [3 terminal guarded measurement]	$>10^{10}$ Ω and <50pF	$>10^{10}$ Ω and <50pF

Response Time

Recover from overload and settle with an error <0.01%

Filter Out	<2 msec
μV Noise	<2 sec
40dB	<3.5 sec

[40dB time is for a source impedance <5kΩ].

To settle with an error <0.1%

From overload	<6 sec
On range change	<3 sec

In addition the following response times are selected by push buttons:

10 SEC for measurements above 15Hz
3 SEC for measurements above 50Hz
1 SEC for measurements above 350Hz

The reading scatter is not greater than

15Hz - 50Hz	at 10 SEC	±2 digits
50Hz - 350Hz	at 3 SEC	±1 digit
above 350Hz	at 1 SEC	±1 digit

INTERFERENCE REJECTION – SERIES MODE

The ratio of the r.m.s. interference at the input terminals to the reading error. Figures apply for interference up to 120% of full scale on each range. Note limit to maximum input on Range 5.

Filters OUT

At the mains supply frequency >70dB
Applies for 50Hz ±2% or 60Hz ±2%
Slight adjustment required for 60Hz

Filter μV NOISE

Range 0, without filtering, has typically ±2μV of noise
This filter gives additional noise rejection of 25dB at 50Hz and is flat at 60dB above 5kHz.
It is inoperative on other ranges.

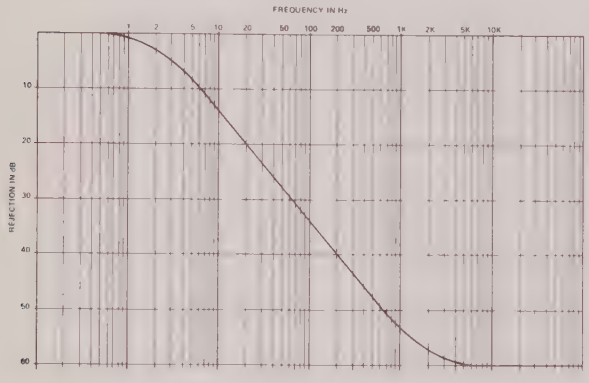


Figure 1.3 μV Noise Filter

Filter 40dB

On all ranges gives additional 40dB at 50Hz, increasing at 20dB/decade. Its selection inhibits the action of μV NOISE filter.

DC voltage up to the maximum permitted overload causes no error.

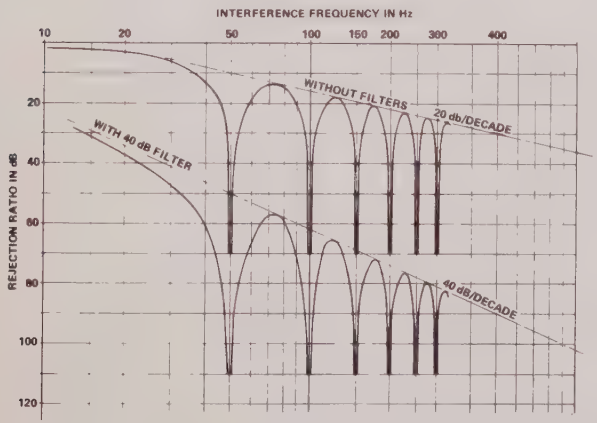


Figure 1.4 40dB Filter

The curves show the rejection of the mains derived interference. A digital servo keeps the notches locked to the mains frequency, even when this varies about a nominal 50Hz.

INTERFERENCE REJECTION – COMMON MODE

The ratio of the r.m.s. interference, applied between signal source and instrument ground [chassis], to the reading error, when there is 1kΩ unbalance in the high and low signal paths. The maximum common mode must not exceed 500V d.c. or peak a.c.

With Guard taken to Low at the voltmeter [2 terminal measurement]

DC	>140dB		
50Hz, without filters	>140dB	DC	>120dB
50Hz, with 40dB filter	>174dB	50Hz	> 70dB

With Guard taken to source of common mode [3 terminal measurement]

50Hz, without filters	>165dB	50Hz	> 80dB

NOTE: 174dB is the greatest measurable ratio since it is the ratio of the maximum permitted interference [500V] to the smallest digit [1μV]. This performance is maintained even when the lead unbalance is considerably in excess of 1kΩ.

TEMPERATURE RANGE

Operation: This specification applies for operation in the ambient range 0-45°C. No damage will result from operation between -10°C and 50°C.

Storage: The complete instrument may be stored at ambients between -20 and 60°C. The upper limit may be extended to 80°C provided that the Weston reference cell is first removed.

MAINS SUPPLY

This specification relates to supplies of 117/234V + 10% - 15% 50Hz or 60Hz. A slight modification is necessary in order to achieve full rejection of interference when the supply is 60Hz. Consumption 60VA.

FAN OUT UNIT EX3052

Outputs

Common emitter transistor stages with 1.5kΩ load to a nominal -12V supply, capable of sinking a further 5mA load current.

Inputs

High (Logic 0)	Input Voltage -0.5V ±0.5V
	Input Current <0.5mA
Low (Logic 1)	Input Voltage -12V ±3V
	Input Current <2mA

Pulse Sample

Pulse amplitude -12V ±3V
Duration >10μS
Input impedance >10kΩ

FAN OUT UNIT EX3054

Outputs

Common emitter transistor stages with 1.5kΩ load to a nominal +12V supply, capable of sinking a further 10mA load current.

Inputs

High (Logic 1)	Input Voltage +12V ±3V Input Current <1mA
Low (Logic 0)	Input Voltage +0.5V ±0.5V Input Current <0.5mA

Pulse Sample

Pulse amplitude +11V ±3V
Duration >10μS
Input impedance >10kΩ

DIMENSIONS

Height (with feet) 5.9in., (150mm)
Height (without feet) 5.16in., (131mm)
Width 17.6in., (447mm)
Depth 19.05in., (484mm)

WEIGHT

35lb., (16kg.,) including all sub-units

ACCESSORIES

Each voltmeter is supplied with an accessory kit which contains:-

- Signal input lead
- Two test prods
- Two crocodile clips
- Spare fuses
- Mains supply lead

ORDERING DETAIL

LM1604 Digital Voltmeter - DC only in bench case

LM1604/05 Digital Voltmeter - DC & AC in bench case

EX1605 Kit to convert LM1604 to LM1604/05

EX3051 Rack mounting kit for LM1604 and LM1604/05, consisting of two ears with handles to replace existing handles

EX3055 Auto-Range Plug-In Board

EX3052 Fan-Out Unit - negative logic

EX3054 Fan-Out Unit - positive logic

SECTION 2

OPERATION

GENERAL

The LM1604 and LM1604/05 voltmeters are supplied fully set up and ready for use. The accessory kit contains a signal input lead which can be fitted with either test prods or crocodile clips. A mains input connector is also included.

PRELIMINARY ADJUSTMENTS

Figure 2.1 Preliminary Adjustments

1. Check the setting of the mains voltage selector plug at the rear of the instrument, noting that voltages from 100V to 130V can be used on the nominal 115V setting and that the range of the nominal 230V setting is 200V to 260V.

2. Check the value of the fuse carried in the holder on the rear panel of the instrument - 500mA SLO-BLO for 230V and 750mA SLO-BLO for 115V.

3. Connect a suitable plug to the mains lead:

RED - LINE
BLACK - NEUTRAL
GREEN - EARTH

or, on instruments having mains leads coded in the international colours:

BROWN - LINE
BLUE - NEUTRAL
GREEN/YELLOW - EARTH

4. Insert the appropriate connector of the mains supply lead into the POWER IN socket on the rear panel of the instrument. Connect the other end of the supply lead to the a.c. mains.

FRONT PANEL CONTROLS

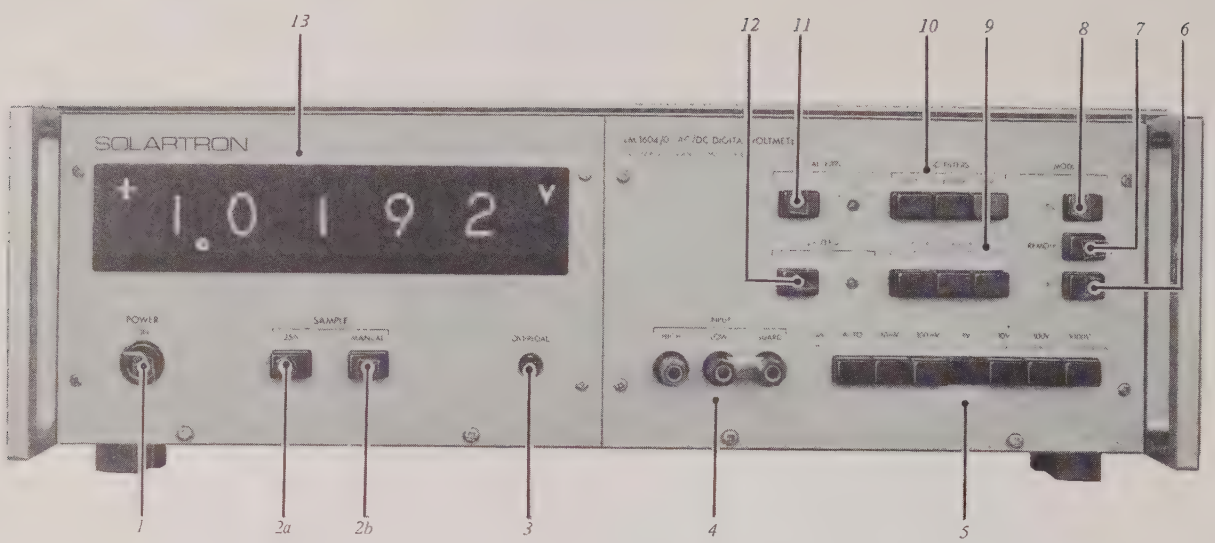


Figure 2.2 Front Panel Controls

1. POWER ON Switch: A toggle switch for applying mains power to the instrument.

2a. SAMPLE - 25/s: Automatically commands the display of each measurement, updating the reading 25 times each second.

2b. SAMPLE-MANUAL: Commands the display of the next measurement which follows operation of the button.

2c. SAMPLE-Remote: With both buttons released, the command must be applied as a pulse or as a result of contact closure, via an internal connector.

3. OVERLOAD Indicator: This flashes when the input voltage equals or exceeds the upper limit of the range in use.

4. INPUT: Three terminals, HIGH, LOW and GUARD are provided. For most applications LOW is connected to GUARD with the link supplied with the instrument and the voltage to be measured is applied to the HIGH and LOW terminals. When full common mode rejection is required, the link is removed and a three-way input lead used [see Three Terminal Measurements].

5. RANGE SELECTOR: Seven push-buttons giving choice of AUTO [automatic] range selection, on d.c. ranges 0-4 only, or manual selection of the 10mV, 100mV, 1V, 10V, 100V, 1 000V d.c. or 100mV, 1V, 10V, 100V, 750V a.c. ranges.

6. AC: Sets up the instrument for manual control of range selection on a.c. measurement only.

7. REMOTE: Any a.c. or d.c. range may be selected remotely via an optional Fan-out Unit when fitted.

8. DC: Sets up the instrument for manual control of range selection on d.c. measurement only.

9. AC RESPONSE TIME: A group of filters for a.c. measurement use only. 10s is for use at frequencies above 15Hz; 3s for frequencies above 50Hz and 1s for frequencies above 350Hz.

10. DC FILTERS: In the OUT position, the input is not filtered, the function of the push-button being primarily to release either of the other two DC FILTER buttons.

μV NOISE is normally required on the 10mV range to reduce noise [approximately $\pm 2\mu$V without it]. It does not affect the other ranges and may be left in.

The third button gives an additional 40dB rejection of noise at 50Hz increasing at 20dB per octave.

11. CAL: With the CAL push button depressed, the associated pre-set control can be adjusted to calibrate the instrument against an internal reference voltage.

12. μV ZERO: The display can be set to zero on any range by adjustment of the pre-set control when the μV ZERO push button is depressed, or zeroed on the 10mV range with the input short-circuited, for greater accuracy.

13. DISPLAY: The numerals are displayed by cold cathode tubes. The maximum reading is 19999 and the decimal point is automatically moved to a position appropriate to the range in use. Polarity is displayed as a + or - sign on d.c., while on a.c. a $\sim$ is shown. A legend to the right of the numerals indicates mV or V.

REAR PANEL CONTROLS

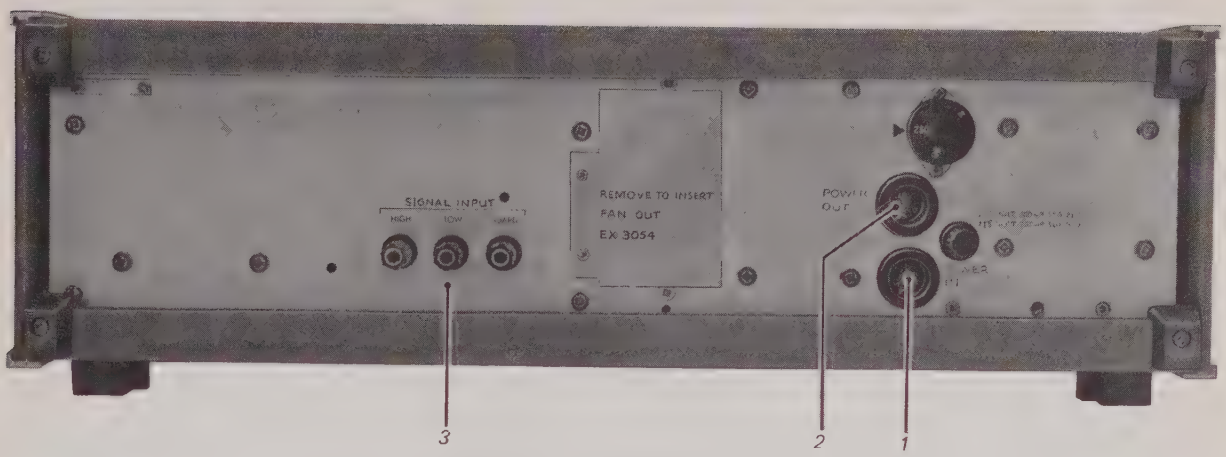


Figure 2.3 Rear Panel Controls

No switchable controls are fitted to the rear panel. Certain items, in addition to the Mains Selector Plug and Mains Fuse, are however located on the panel.

1. POWER IN connector.

2. POWER OUT connector providing mains power, unfused and switched by the voltmeter POWER ON switch, for distribution to other equipment in a system.

3. A second set of SIGNAL INPUT terminals, identical to and in parallel with those on the front panel.

CAUTION
When making three terminal input measurements, ensure that the link between LOW and GUARD, on the front and rear panel SIGNAL INPUT terminals, is removed.

CALIBRATION

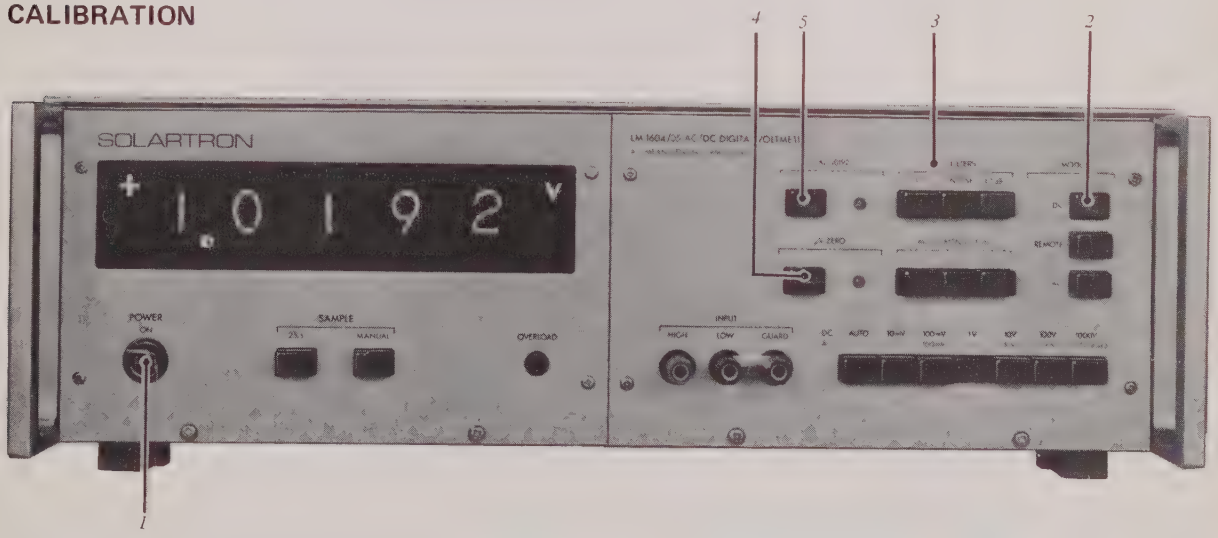


Figure 2.4 Calibration

The following procedure should be carried out daily or before taking a measurement which has to be made to the highest order of accuracy.

1. Switch POWER on and wait 15 minutes.

2. Lock in the DC mode push-button.

3. Set the DC FILTER to OUT.

4. Press and hold the μV ZERO push-button and adjust its pre-set control with a screwdriver to give a display of 0000. Release the μV ZERO push-button.

5. Press and hold the CAL push-button and adjust its pre-set control with a screwdriver to give a display of +1.0192V. Release the CAL pushbutton.

6. The instrument is now calibrated ready for use on all a.c. and d.c. ranges.

NOTE:
For optimum accuracy, when used on the 10mV range, the input HIGH and LOW connections should be short circuited remote from the terminals and the μV ZERO pre-set control adjusted to give a display of 0000 without depressing the μV ZERO push button.

DC VOLTAGE MEASUREMENT

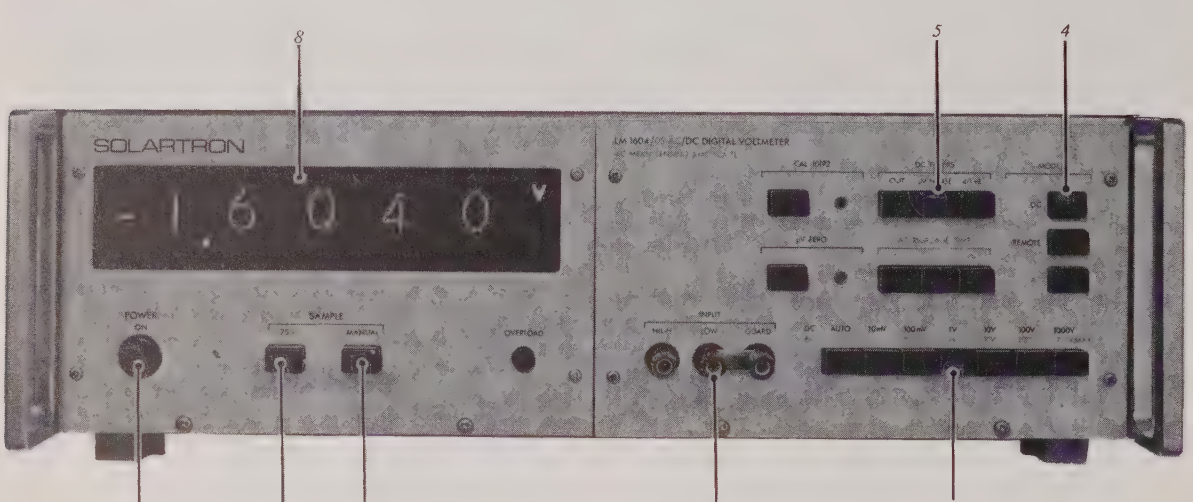


Figure 2.5 D.C. Voltage Measurement

CAUTION
The maximum d.c. input voltages that may safely be applied to the instrument are:

250V on ranges 0-4 [10mV - 10V] and 1 000V on ranges 4 and 5.

1. Switch POWER on.

2. Choose an appropriate range. If the input voltage is unknown, select the 1 000V range. If the auto range kit is fitted [EX 3055] and the AUTO button is pressed, the instrument will automatically select the appropriate range from ranges 0-4.

3. Connect the input lead to the unknown voltage source, red to signal high and black to signal low.

4. Lock in the DC MODE push-button.

5. Set the DC FILTER as required [see para. 10 "Front Panel Controls"].

6. Depress 25/s for continuous measurement or

7. Depress MANUAL for 'single shot' operation.

8. Read the voltage from the display, if necessary down-ranging to obtain greater sensitivity.

NOTE [a]:
In circumstances where the specified degree of interference rejection is adequate, the instrument is operated with the black [LOW] terminal strapped to the green [GUARD] terminal. For certain applications, particularly data logging, increased common mode rejection can be obtained by independent use of the GUARD terminal in conjunction with a three-way input lead. Refer to paragraphs on interference rejection for fuller details.

NOTE [b]:
If the OVERLOAD indicator flashes, the displayed reading should be ignored and the instrument up-ranged appropriately.

NOTE [c]:
If the displayed reading is unsteady, it may be stabilised by depressing either the μV noise or 40dB button as necessary. Use of these facilities, however, will increase the time taken for the display to reach its final value. [Refer to the specification paragraph 'Response Time' for full details].

AC VOLTAGE MEASUREMENT

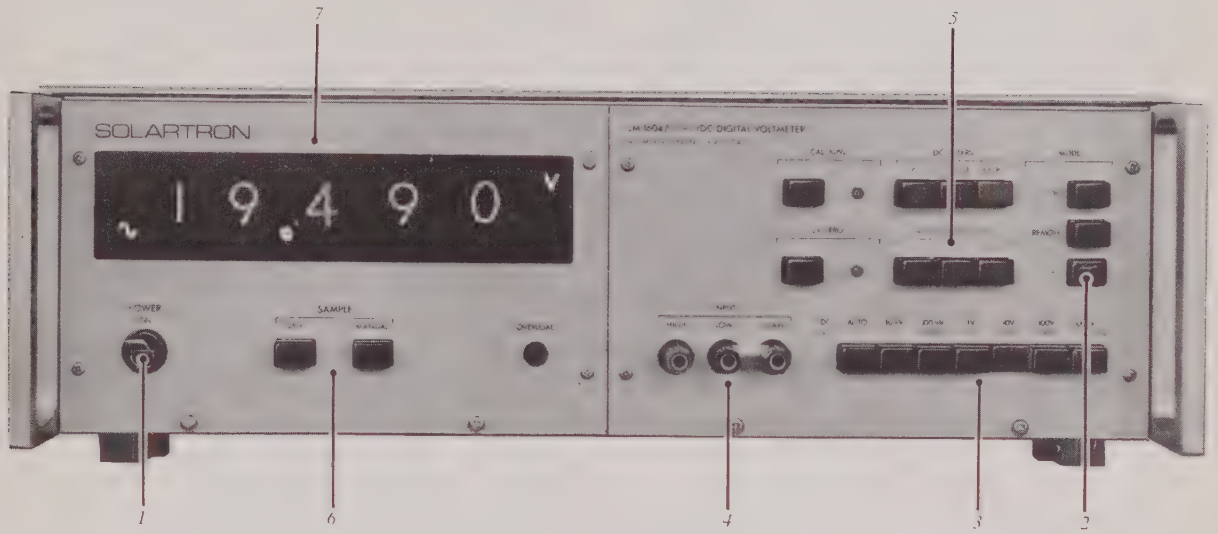


Figure 2.6 A.C. Voltage Measurement

CAUTION:
The maximum a.c. input voltages which can safely be applied to the instrument are:-

250V peak on the 100mV and 1V ranges.
1 000V peak on the 10V, 100V and 750V ranges.

1. Switch POWER on.

2. Lock-in the AC MODE push-button.

3. Choose an appropriate range. If the input voltage is unknown, select the 750V range.

4. Connect the input lead to the unknown voltage, red to signal high and black to signal low.

5. Select a suitable AC RESPONSE TIME [see para. 9 "Front Panel Controls"].

6. Select 25/s or MANUAL SAMPLE, as required.

7. Read the voltage from the display. If necessary, down-range to obtain greater sensitivity.

NOTE:
If the frequency of the input is unknown, any AC RESPONSE TIME may be selected but the time taken for the display to reach its final value may be increased. [Refer to specification paragraph Response Time.]

INTERFERENCE REJECTION

DC Measurements

The input circuits of the voltmeter are fitted within a screening box which is thoroughly isolated from the main chassis of the instrument, but connected to the GUARD terminal. This arrangement enables interference signals, developed across the signal source resistance by common mode current, to be minimised.

CAUTION
When the instrument is used with LOW and GUARD terminals strapped together by the link provided, it should be noted that the link may be at a potential of 500V d.c. or peak a.c. if high common mode voltages are present.

Two Terminal Measurements

For normal laboratory work, sufficient d.c. common mode rejection will be obtained using the two terminal arrangement shown in figure 2.7 where the LOW terminal is externally strapped to the GUARD terminal. The source resistance is Rs and the leakage resistance to chassis R_L.

For a 50Hz a.c. common mode signal, the 600pF stray capacitance C_s shunts the leakage resistance R_L.

Detailed rejection figures are given in the specification.

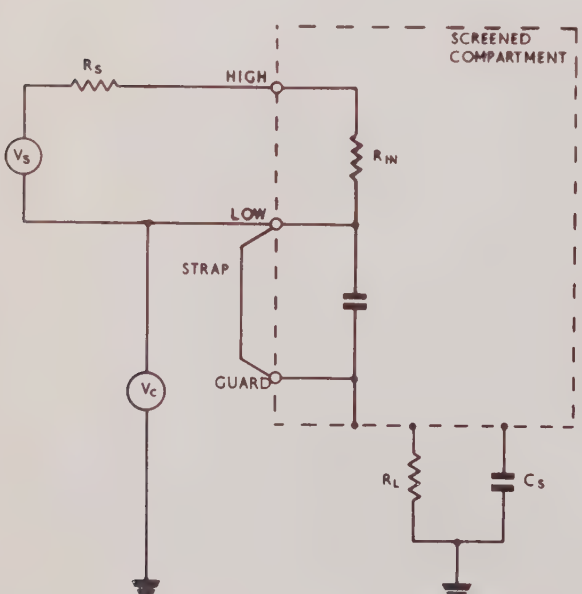


Figure 2.7 Two Terminal Measurements

Three Terminal Measurements

Where the source of common mode voltage can be identified, the rejection figure can be increased even further [for both a.c. and d.c. common mode] by using the three terminal measurement procedure shown in figure 2.8. The strap between LOW and GUARD has now been removed and a three-way signal lead is used. Thus an alternative path for common mode currents is provided, through the GUARD lead and R_L.

CAUTION
Ensure that GUARD is NOT strapped to LOW on either front or rear input terminals before carrying out three terminal measurements.

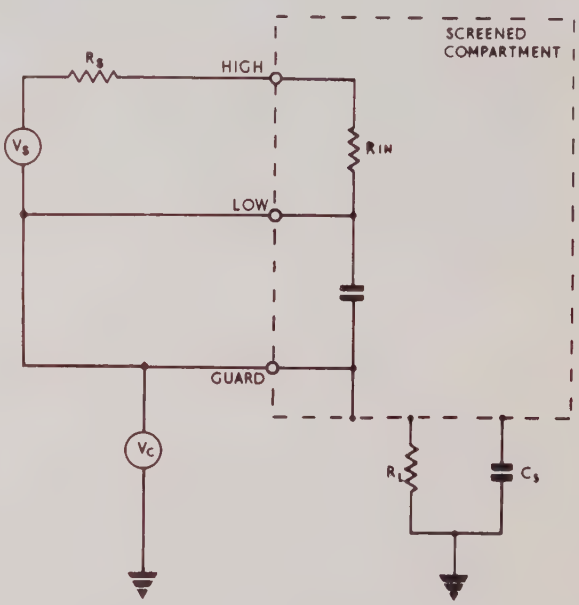


Figure 2.8 Three Terminal Measurements

SECTION 3

TECHNICAL DESCRIPTION

BASIC CONCEPT

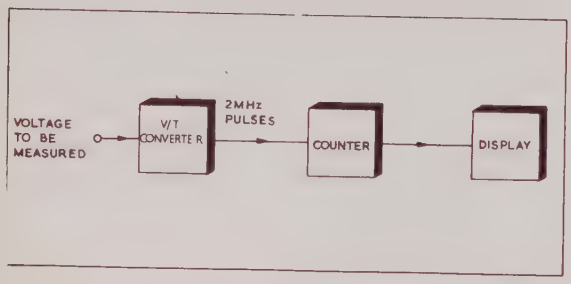


Figure 3.1 Basic Principle

The voltage to be measured is converted to a time period during which pulses are accumulated in a counter. At the end of the time period the contents of the counter are transferred to a display. The display thus provides a digital indication of the number of pulses passed to the counter and hence of the amplitude of the voltage applied to the input terminals.

GENERAL PRINCIPLES OF DUAL RAMP VOLTMETERS

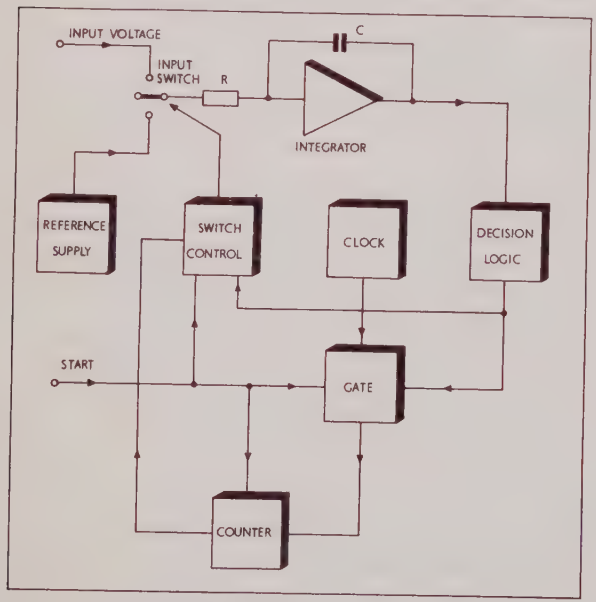


Figure 3.2. Basic Dual Ramp Block Diagram

A measurement cycle is started by commanding SWITCH CONTROL to connect the voltage to be measured to the INTEGRATOR. At the same time, the COUNTER is set to zero and the GATE opened. Pulses from the CLOCK then accumulate in the counter and the integrator output rises as a ramp - the rate of rise being proportional to the input voltage. If the counter has a "full house" of 19 999, then the 20 000th clock pulse will return it to zero. It is arranged that when the counter reaches 19 999, it sends a pulse to switch control which opens the input switch. The RAMP UP is thus terminated after a period of time which depends upon the frequency of the clock - a 1MHz clock giving a nominal ramp up period of 20msec. At this point, a voltage [V_1] will have been stored on the integrator capacitor directly proportional to the input [V_{in}] and the time [T_1] for which the input was connected.

Thus: $$V_1 = \frac{V_{in} \cdot T_1}{RC} \text{ volts} \qquad [1]$$

where R and C are the integrator feedback components.

A REFERENCE SUPPLY, arranged to be of opposite polarity to the voltage being measured, is now connected to the integrator input by SWITCH control. The integrator output thus ramps down towards zero at a rate proportional to this reference voltage. Meanwhile the clock is still feeding pulses into the counter which again started from zero as ramp down commenced.

When the ramp reaches zero, this is detected by the DECISION LOGIC which closes the gate and commands switch control to disconnect the reference supply hence terminating the ramp down period.

The total number of pulses in the counter is now directly related to the time taken for ramp down and, because the reference voltage is constant, it is also proportional to the voltage [V_1] which was stored at the end of ramp up.

If, during ramp down, the integrator output is v and the reference voltage is Vr,

Then $$v = V_1 - \frac{Vr \cdot t}{RC} \text{ volts} \qquad [2]$$

When v = 0 at the end of ramp down then

$$V_1 = \frac{Vr \cdot T_2}{RC} \text{ volts}$$

where T_2 is the ramp down time.

Hence from [1] and [2]

$$\frac{V_{in} \cdot T_1}{RC} = \frac{Vr \cdot T_2}{RC}$$

$$V_{in} = V_r \cdot \frac{T_2}{T_1} \text{ volts}$$

Now the number of clock pulses accumulated in the counter for a clock frequency of fHz is given by

$$N = Tf \text{ pulses}$$

and thus

$$T = \frac{N}{f} \text{ seconds}$$

$$\therefore V_{in} = V_r \cdot \frac{N_2}{f} \cdot \frac{f}{N_1} \text{ volts}$$

$$= V_r \cdot \frac{N_2}{N_1} \text{ volts}$$

But Vr is a fixed reference supply and is a constant. Similarly N_1 is fixed

$$\therefore V_{in} \propto N_2$$

and is independent of clock frequency.

In other words, the number of pulses accumulated by the counter during ramp down is in direct proportion to the voltage being measured and can be displayed digitally.

The main advantage accruing from the use of the ramp technique lies in the voltmeter's inherent ability to reject series mode interference without the use of filters. If the integration time is made equal to the 50Hz mains period, then the voltmeter will read the mean value of the input, effectively ignoring interference at 50 Hz and its harmonics since the mean value of a sine wave over a complete cycle is zero.

PRINCIPLES OF THE LM1604 DUAL RAMP VOLTMETER

The Solartron LM1604 voltmeter operates basically as described in the preceding section but with certain refinements incorporated which significantly improve both accuracy and series mode rejection.

[1] A digital servo system continuously monitors the 50Hz mains frequency and, by modifying the frequency of the clock, ensures that ramp up lasts for exactly one mains period. This provides the maximum possible series mode rejection even though the mains frequency may vary from the nominal 50Hz.

[2] A 33μsec delay is introduced between the end of the ramp up period and the beginning of ramp down. This allows time for the correct polarity reference supply to be selected and prevents the possibility of inaccuracies being introduced due to switching transients and component settling time.

[3] It is arranged that during ramp down, the clock feeds 2MHz pulses into the counter. Thus, for a full scale display of 19 999 to be registered, the time required for ramp down is nominally only 10 msec. This leaves a 10msec period before the next measurement cycle starts which is used to drift correct the integrator and apply any necessary correction to the clock thereby further enhancing the voltmeter accuracy.

Sequence of Operation

At the commencement of a measurement cycle the unknown input is connected to the integrator via an input amplifier - the use of which increases the voltmeter input impedance and facilitates range switching. Ramp up is started and the counter accumulates 1MHz clock pulses until a gate detects a count of 19 999 and terminates ramp up preventing any further pulses from being fed into the counter. A reset pulse is now generated which returns the counter to zero. The nominal 20msec ramp up time is compared with the 50Hz mains period - any discrepancy being noted and stored.

A 33μsec delay period now follows, during which the polarity of the voltage developed on the integrator capacitor is examined and stored and the appropriate sense reference supply selected.

After the delay the reference supply is connected to the integrator and ramp down commences. A detector determines the instant at which the integrator output reaches zero and terminates ramp down. [Note that when a "full house" of 19 999 is registered, the ramp down time will be a maximum of 10msec.]

Approximately 9msec. before the end of the measurement cycle, the drift correct period starts, during which:-

[a] The integrator is zeroed and drift corrected,
[b] The contents of the counter together with polarity information is transferred to the display.
[c] The result of the comparison previously made between ramp up and mains periods is used to modify the frequency of the 2MHz clock oscillator ensuring an integration period which is locked to the 50Hz supply.

A second reset pulse is generated towards the end of the drift correct period and resets the counter to zero in readiness for the next ramp up period .

The next measurement cycle is initiated by a 25Hz pulse derived from the 50Hz supply which triggers the ramp up circuitry.

POWER SUPPLIES

Interference Rejection

Considerable care in design has been taken to ensure maximum rejection of common mode interference. A three terminal input is provided with the guard rail connected to a screening box enclosing the floating section of the instrument. By connecting the guard terminal to the source of interference, common mode currents will bypass the input amplifier and flow via the screened box and stray impedances to earth.

Transformer coupling between the floating and earthy sections gives complete isolation permitting earthed external equipment to be connected direct to the voltmeter without degrading the noise rejection specification.

All power rails for the floating section are derived from an inverter supplied from a stabilised d.c. supply. An isolation transformer connected between the secondary of the mains transformer and this d.c. power supply provides the required isolation between floating circuits and mains earth.

Figure 3.3 shows schematically the power and signal connections of the voltmeter, illustrating the isolation between the floating sections and earth.

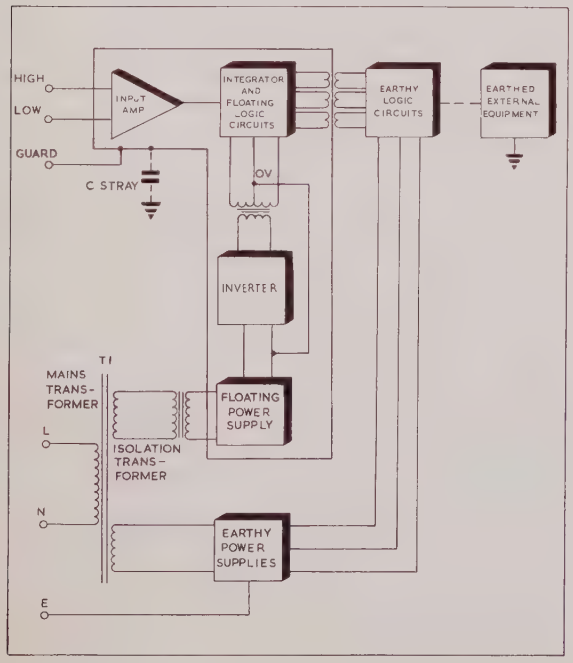


Figure 3.3 Interference Rejection - Isolation from Earth

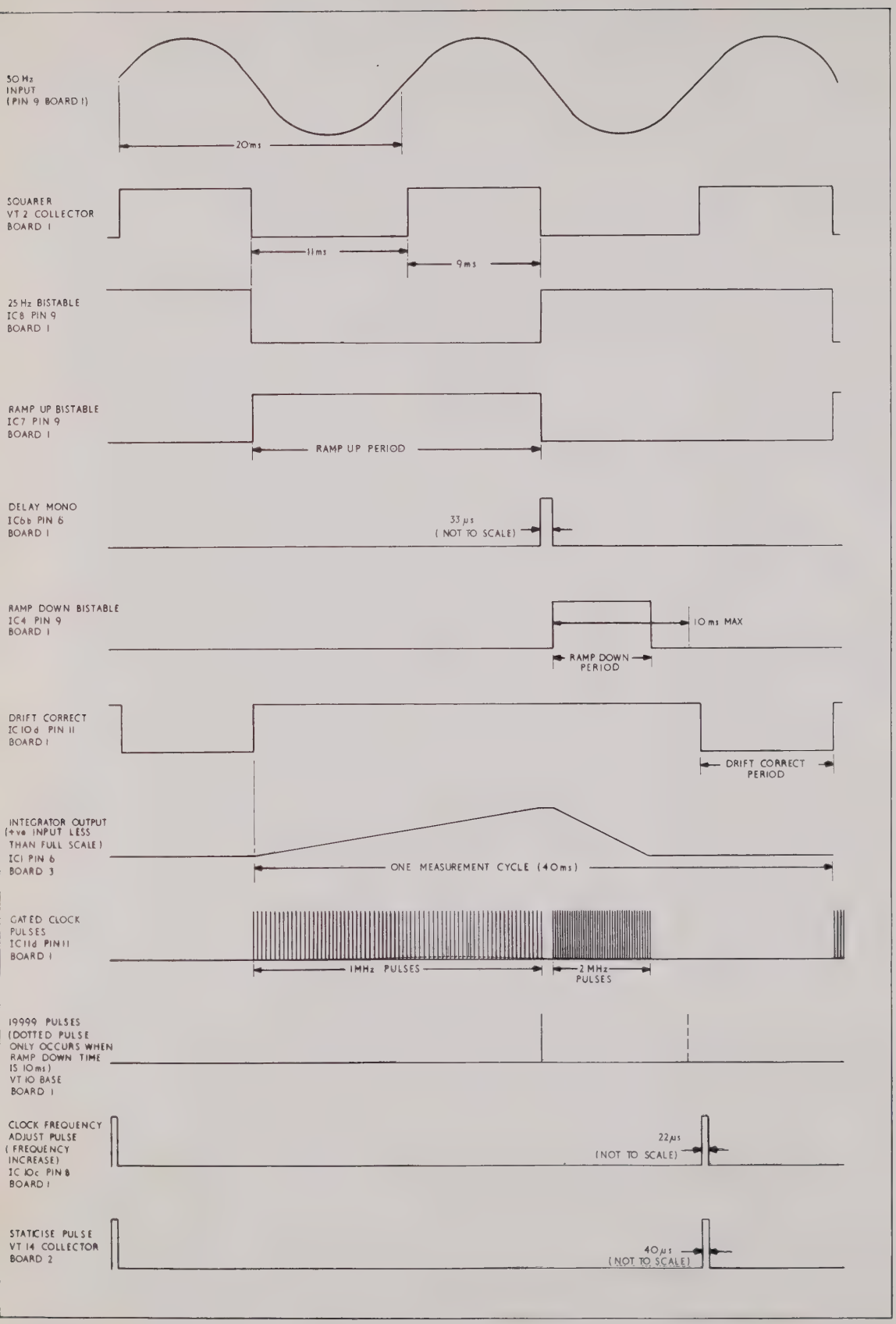


Figure 3.4 Timing Diagram - Principal Waveforms

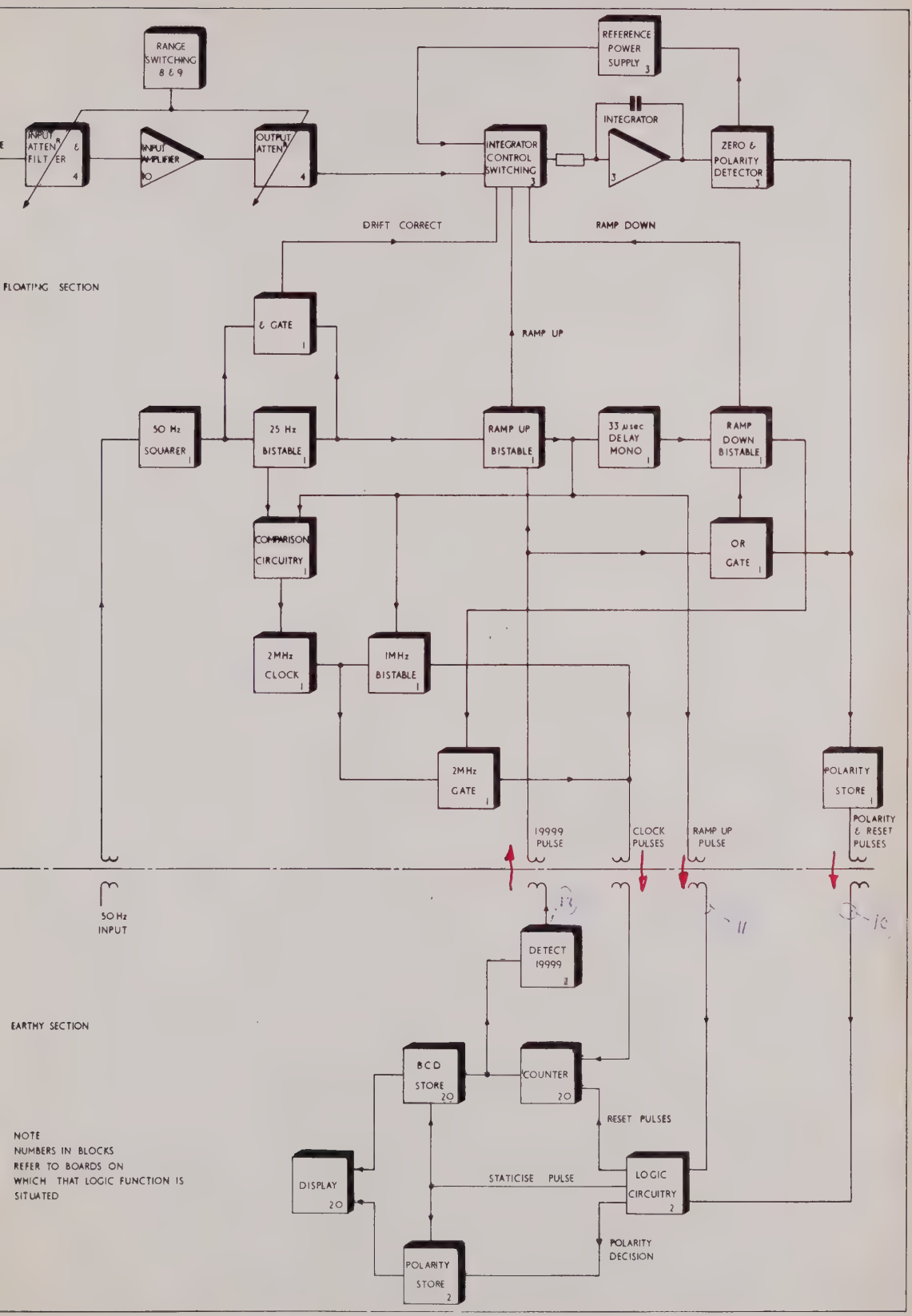


Figure 3.5 Block Diagram - Complete Voltmeter

Power Supplies

Mains Input

Mains supplies are fed in via plug PLA and 'power on' switch SA to the split primary winding of mains transformer T1 which can accommodate nominal 115V or 230V inputs. A mains outlet is provided by socket SKE and is primarily intended for supplying power to external equipments in, for example, a data logging system when SA acts as the system power on switch. C1 and C2 are included to filter out mains spikes with bleed resistors R4 and R5 being fitted for safety reasons.

Earthy Supplies

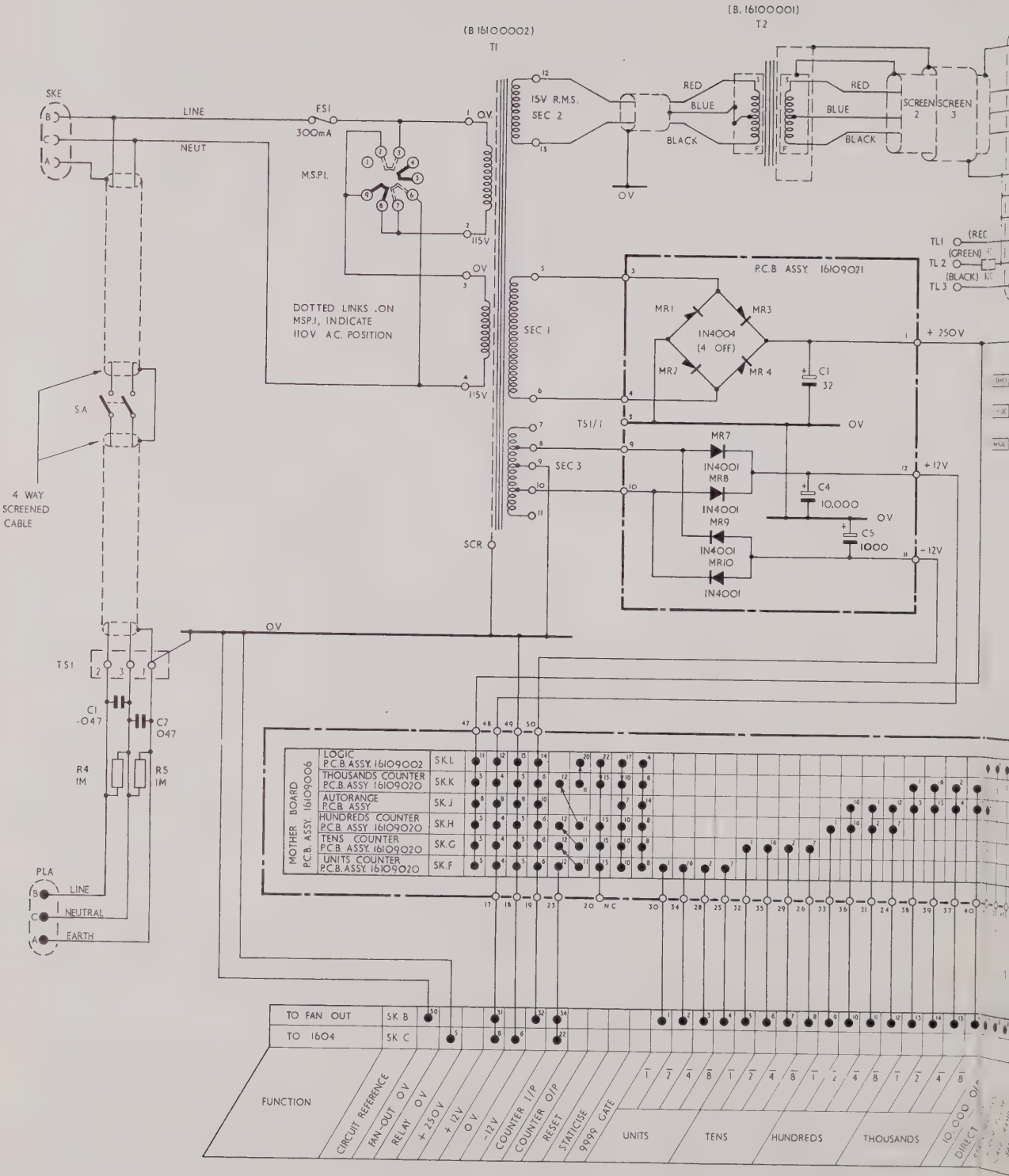
The output from T1 secondary 1 is full-wave rectified by the bridge rectifier MR1-MR4 and smoothed by C1 and supplies +250 volts to the display unit for the neon tube indicators.

Secondary 3 output is full-wave rectified providing smoothed $\pm$12 volts for the display and fan out units.

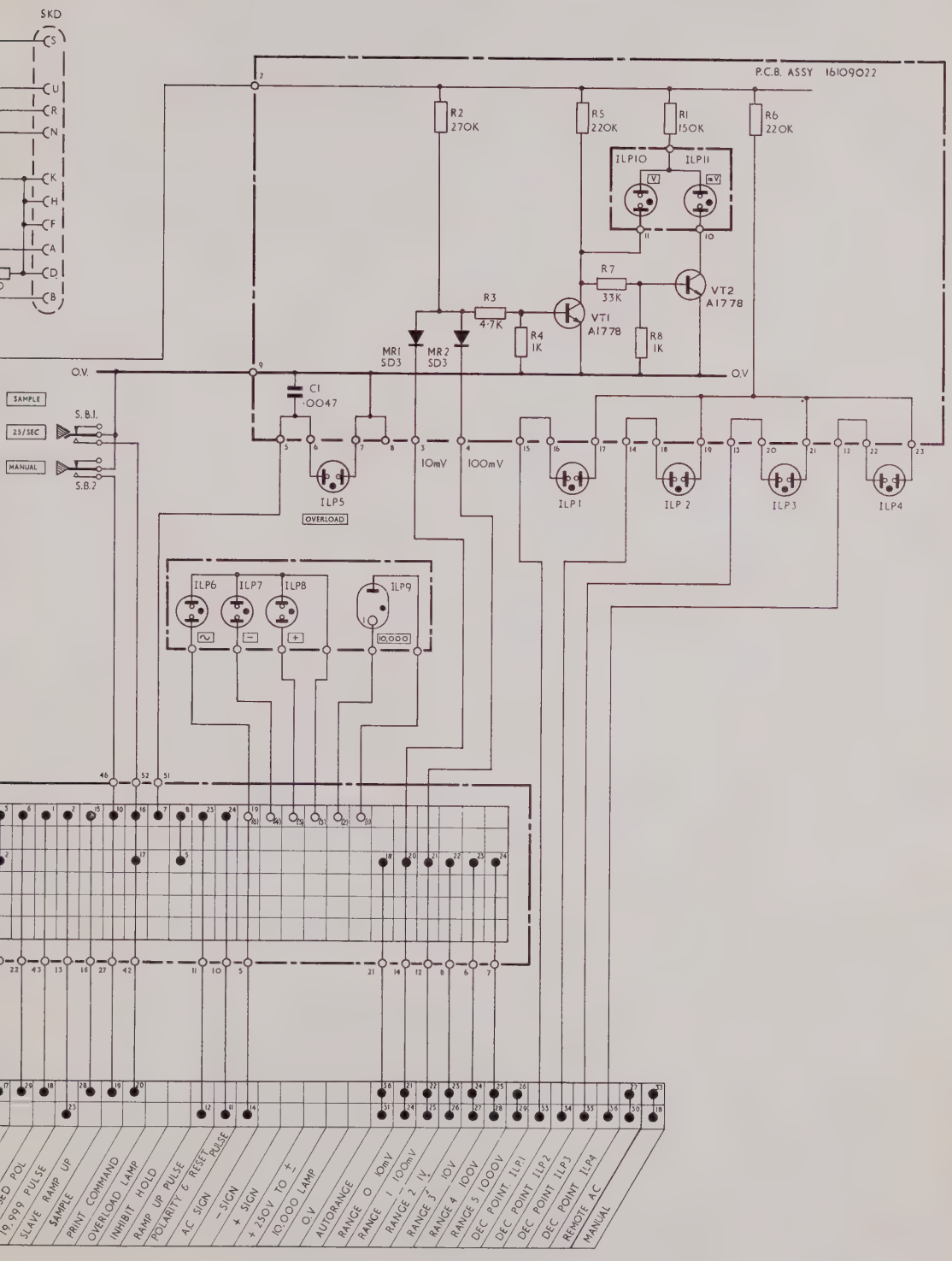
All the former supplies are referenced to mains earth.

Floating Supplies

Secondary 2 of the mains transformer is connected to the primary of the isolation transformer T2. Screened windings and the use of a double screened cable on the secondary side ensure the high degree of isolation required between the floating sections of the instrument and mains earth.


(B 16100002)
T1
(B. 16100001)
T2
SKE
LINE
NEUT
FS1
300mA
M.S.P.I.
DOTTED LINKS ON MSP.I. INDICATE 110V A.C. POSITION
15V R.M.S. SEC 2
RED
BLUE
BLACK
SCREEN 2
SCREEN 3
SEC 1
SEC 3
SCR
P.C.B ASSY 16109021
MR1
MR2
MR3
MR4
IN4004 (4 OFF)
C1 32
+ 250V
TS1/1
MR7
IN4001
MR8
MR9
MR10
C4 10,000
C5 1000
+ 12V
- 12V
OV
115V
TL1 (RED)
TL2 (GREEN)
TL3 (BLACK)
S A
4 WAY SCREENED CABLE
TS1
C1 .047
C2 047
R4 1M
R5 1M
PLA
LINE
NEUTRAL
EARTH
MOTHER BOARD P.C.B. ASSY. 16109006
LOGIC P.C.B.ASSY. 16109002 SK.L
THOUSANDS COUNTER P.C.B. ASSY 16109020 SK.K
AUTORANGE P.C.B. ASSY SK.J
HUNDREDS COUNTER P.C.B. ASSY 16109020 SK.H
TENS COUNTER P.C.B. ASSY. 16109020 SK.G
UNITS COUNTER P.C.B. ASSY. 16109020 SK.F
TO FAN OUT SK B
TO 1604 SK C
FUNCTION
CIRCUIT REFERENCE
FAN-OUT O.V
RELAY O.V
+ 250V
+ 12V
O.V.
-12V
COUNTER I/P
COUNTER O/P
RESET
STATICISE
9999 GATE
UNITS
TENS
HUNDREDS
THOUSANDS
10,000 O/P
DIRECT

01 9.9.GA



Power Supply and Annunciators

Board Nos 6, 21 and 22

D16107000

RANGE SWITCHING AND MODE SELECTION

General

Range selection is achieved by using relay contacts to switch the input attenuator and to control the amplifier gain. The relays can be called either manually by means of range push-button switch SH on the front panel, remotely from an external source [directly or via a fan-out unit] or on d.c. ranges 0-4 automatically.

Mode switch SJ in conjunction with a seventh push-button on SH, determines which method is to be used to select the ranges and whether the voltmeter is programmed for a.c. or d.c. measurement. The DC position provides a mechanical reset for the other two push-buttons.

While mechanical interlocking ensures that only one push-button on each bank of switches will remain depressed, it is possible to release all buttons together. In this event, the voltmeter will remain in the d.c. mode but the input voltage will be disconnected until one of the range buttons is pressed.

V or mV Indication

Operating in conjunction with the relay decode and drive boards 8 and 9, a mV or V neon in the display unit is struck to indicate the range in use. The neon drive circuitry is contained on board 22 in the display unit and consists of transistors VT1 and 2 driven by the OR gate MR1, MR2. On the volt ranges, both diodes are reverse biased and VT1 is switched on. The 0 volts on VT1 collector switches off VT2 causing the V neon to strike while the mV neon is extinguished. Should the cathode of either MR1 or MR2 be returned to 0 volts [as when the two mV ranges are selected], VT1 cuts off and ILP10 extinguishes. VT1 collector now rises to approximately +30 volts and VT2 switches on to strike the mV neon ILP11.

DC Mode

Mode switch SJ is in the position shown and 0 volts is applied from PLC pin 5 via SJ2a and SH1b to the range switches SH2 - SH7. The 0 volts on PLC pin 18 is routed to the fan out unit [if fitted] to inhibit any remote a.c. command signals. As no information can now be applied to PLC pin 30, VT1 conducts and the 0 volts on its collector is inverted by VT3 and again by VT4 to supply 0 volts to one end of the d.c. range relays RLA-RLG. Any relay will now energise when +12 volts is connected to the other end of the coil. VT15 and VT2 will both be cut off by VT1 to extinguish the AC indicator and inhibit all a.c. range relays.

Relay Switching

Across each relay coil is an RC network in series with a diode. When switched off, the relay coil resonates with the capacitor. After the first quarter cycle when the coil has transferred its stored energy into the capacitor the diode is reverse biased and no further current can flow in the oscillatory circuit. The relay now de-energises and the charge held by the capacitor is dissipated in the resistor. By this method, relay drop out time is reduced to approximately 200μsec.

10mV Range

SH2 connects the 0 volts from SH1b to R14. VT5 conducts, energising RLD via MR18 and RLE via MR9. VT5 also switches on VT10 via MR13 to strike the decimal point neon ILP2 in the display unit. The mV neon ILP11 is energised as a result of the 0 volts applied to PLC pin 24 by SH2.

100mV Range

Depression of SH3, by applying 0 volts to R17, switches on VT6. RLC is energised via MR7, RLE via MR10 and VT11 switched on via MR17 to strike ILP3 in the display unit. The +12 volt level applied to PLA pin 2 is used to command a.c. range relays when fitted. The mV neon is again struck, this time via PLC pin 25.

1V Range

SH4 switches on VT7 and relays RLB and RLE are energised via MR4 and MR11 respectively. VT8 is switched on by VT7 collector and ILP1 struck in the display unit. An a.c. range command is applied to PLA pin 3. Since neither PLC pin 24 nor pin 25 is energised, the mV neon extinguishes and the V neon strikes.

10V Range

SH5 switches on VT9 via R25 and the +12 volts at the collector energises RLA via MR17 and RLE via MR12. +12 volts is applied to PLA pin 4 and, via MR14, to VT10 base. VT10 conducts striking ILP2 in the display unit.

100V Range

SH6 switches on VT11 to energise relays RLF and RLG via MR15 and RLC via MR6. VT12 is switched on via MR18 and conducts to strike ILP3 in the display unit. PLA pin 5 rises to +12 volts.

1 000V Range

SH7 switches on VT13 energising RLF, RLG and RLB via MR16 and MR3. VT14 is switched on via R36 and conducts striking ILP4.

RANGE	RELAY ENERGISED		DECIMAL POINT	PLA PINS ENERGISED	FULL SCALE READING
10mV	E	D	2	NONE	19.999mV
100mV	E	C	3	2	199.99mV
1V	E	B	1	3	1.9999V
10V	E	A	2	4	19.999V
100V	FG	C	3	5	199.99V
1000V	FG	B	4	NONE	1999.9V

Table 3.1 D.C. Ranging

Remote Mode

The range relay drive transistors can also be switched on by applying 0 volts to PLC pins 24-29. These commands can be applied direct from an external source but are more usually supplied via a fan out unit.

When the REMOTE push button SJ2 is not depressed, inhibiting information is routed to the fan out unit via PLC pin 18. Remote ranging commands will now be inhibited within the fan out unit. By operating SJ2, the 0V rail is disconnected from the range switch push buttons and the inhibiting signal removed from PLC pin 18. Range commands applied to the fan out unit will be routed to PLC pins 24-29 and will operate range relays A-G as before.

Should a.c. operation be commanded by applying an appropriate input to the fan out unit, PLC pin 30 will be returned to 0 volts. VT1 will cease to conduct and thus remove the 0 volts from all d.c. range relays by switching off VT4 via VT3. VT15 and VT2, however, will conduct, striking the AC neon ILP6 via PLC pin 14 and applying 0 volts to all a.c. range relays via SKA pin 8. Ranges 2-5 may now be called via transistors VT6, VT7, VT9, VT11 and PLA pins 2-5.

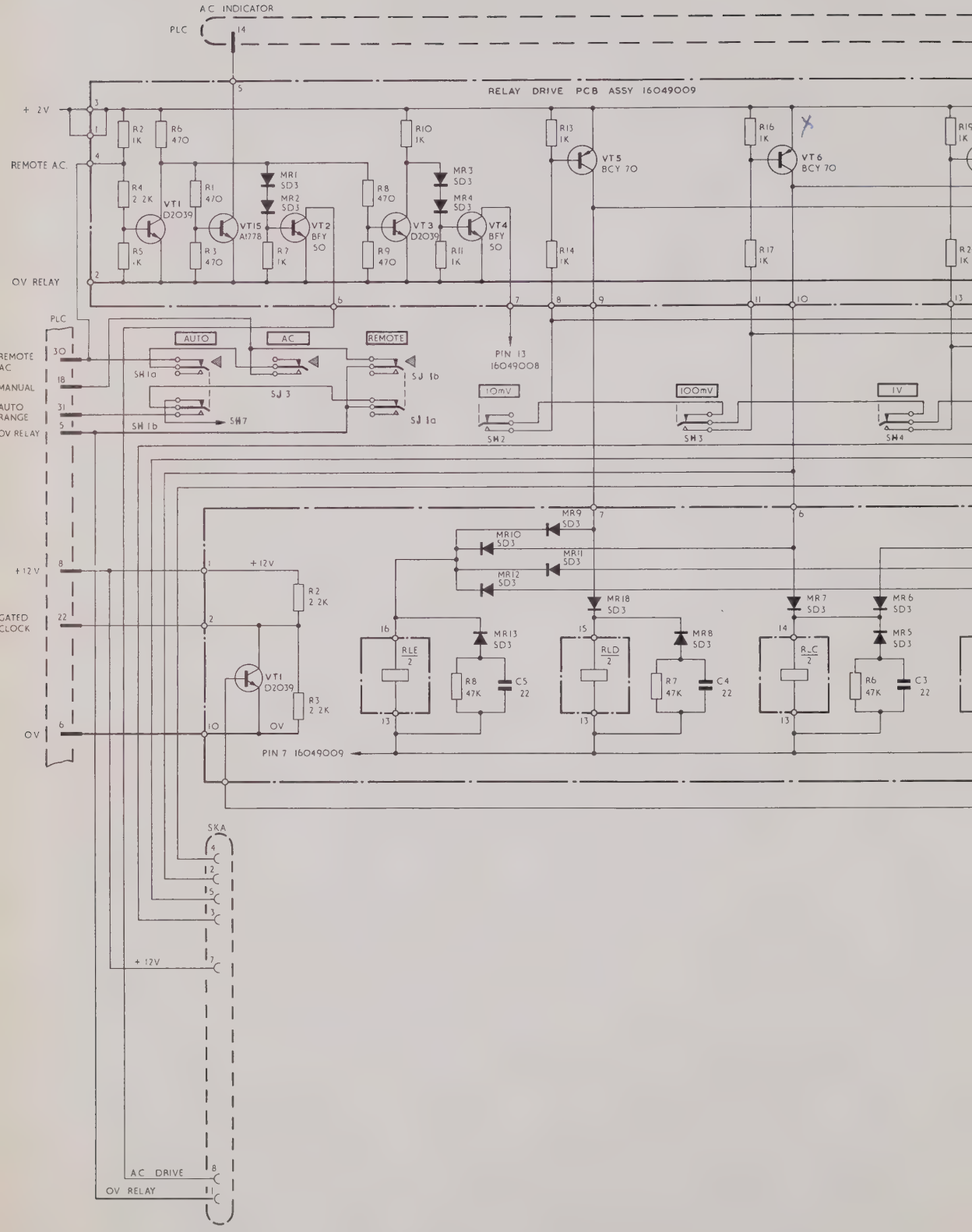
AC Mode

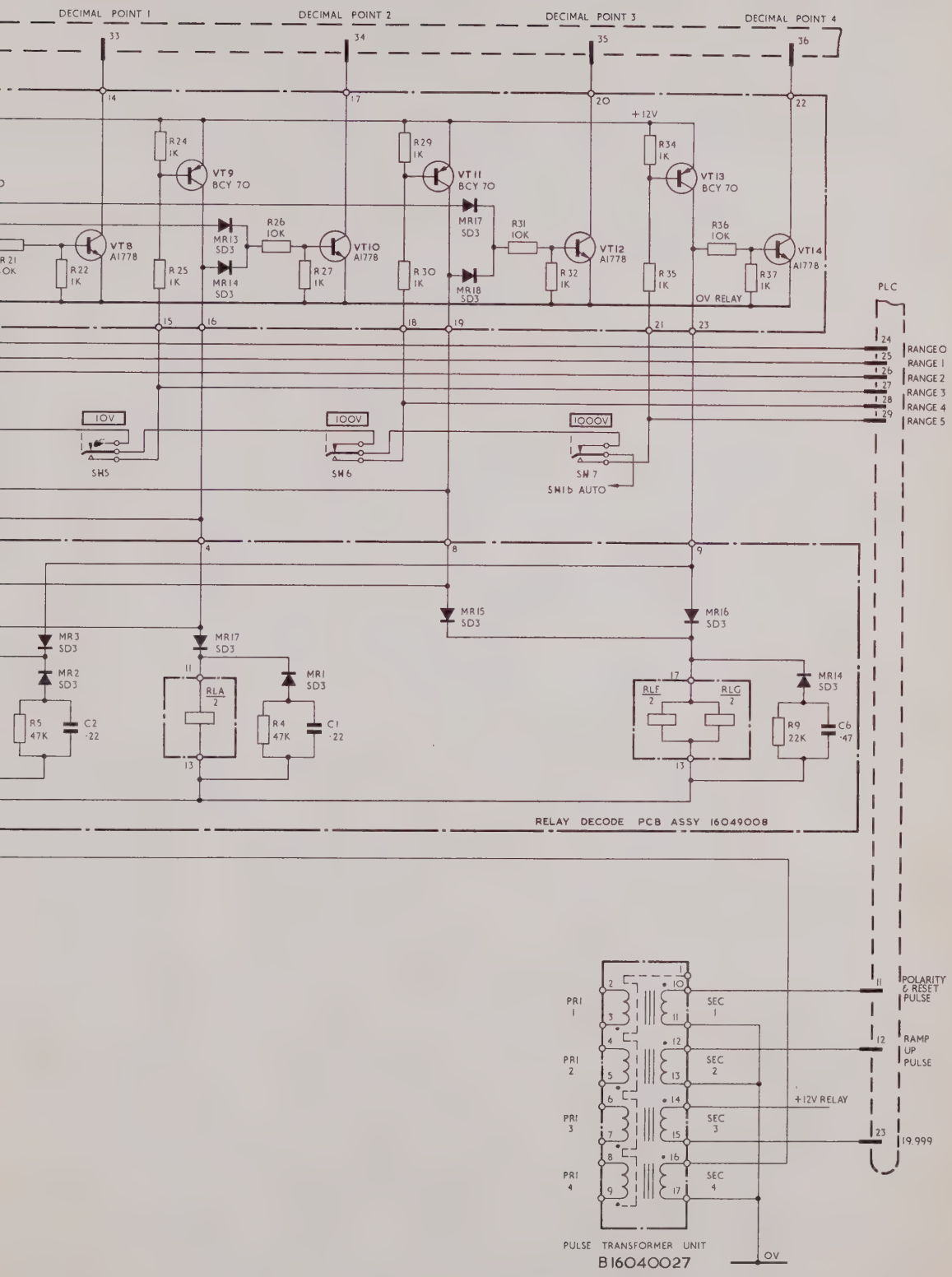
When SJ3 is operated, 0 volts is applied to VT1 base from PLC pin 5 via SJ2b, SJ3 and SH1a. VT1 is cut off inhibiting the d.c. range relays by cutting off VT4 via VT3 but striking the AC neon ILP6 in the display unit via VT15 and PLC pin 14. VT2 is switched on supplying 0 volts to the a.c. range relays via SKA pin 8. AC ranges 2-5 may now be called by means of push buttons SH3-6 via SKA [but only if an EX 1605 a.c. unit is incorporated].

AC ranging is described fully in the section dealing with the EX 1605 a.c. unit.

Auto Mode

When depressed, SH1b disconnects the 0 volts from the range push buttons and applies it to the auto-range board [when fitted] via PLC pin 31. Remote range selection via the fan out unit is inhibited via PLC pin 18, hence no input is present on pin 30 rendering remote a.c. operation impossible. SH1a, by isolating board 9 pin 4, prevents the manual selection of a.c. ranges. Auto ranging commands are now applied to PLC pins 24-29 from the auto range board, the operation of which is described in the section dealing with the auto range unit.


A.C. INDICATOR
PLC
14
RELAY DRIVE PCB ASSY 16049009
+ 2V
REMOTE A.C.
OV RELAY
R2 1K
R6 470
R4 2.2K
R1 470
R5 1K
R3 470
VT1 D2039
VT15 At778
MR1 SD3
MR2 SD3
VT2 BFY 50
R7 1K
R10 1K
R8 470
R9 470
MR3 SD3
MR4 SD3
VT3 D2039
VT4 BFY 50
R11 1K
R13 1K
VT5 BCY 70
R14 1K
R16 1K
VT6 BCY 70
R17 1K
PLC
REMOTE A.C.
MANUAL
AUTO RANGE
OV RELAY
AUTO
AC
REMOTE
SW1a
SW1b
SW7
SW1b
SW1a
PIN 13 16049008
10mV
100mV
1V
SW2
SW3
SW4
+12V
GATED CLOCK
OV
+12V
R2 2.2K
VT1 D2039
R3 2.2K
OV
MR9 SD3
MR10 SD3
MR11 SD3
MR12 SD3
MR18 SD3
MR7 SD3
MR6 SD3
MR13 SD3
MR8 SD3
MR5 SD3
RLE 2
RLD 2
R-C 2
R8 47K
C5 22
R7 47K
C4 22
R6 47K
C3 22
PIN 7 16049009
SKA
+12V
AC DRIVE
OV RELAY



Earthy Wiring - Range and Mode Switching

01 12.5.69

Board Nos 8 and 9

D16047001 SHT 2 OF 2

INPUT AMPLIFIER SWITCHING

General

For the display to register a full-scale reading of 19999, a nominal 20 volts must be applied to the integrator. The same input is required on all voltage ranges, the significance of the displayed reading being altered by moving the decimal point and striking the mV or V neon as detailed in table 3.1. The input amplifier, therefore, is required to deliver a maximum output of 20 volts on all ranges - this being achieved by varying the amplifier gain and using a 1000:1 input attenuator on the higher voltage ranges. The amplifier operating conditions are determined by range relays A-G as in table 3.1.

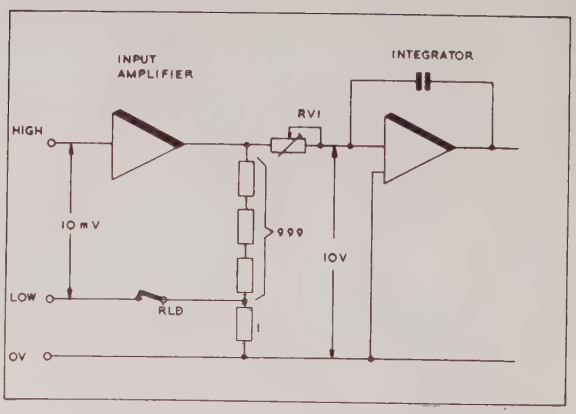


Figure 3.7 Input Amplifier - 10mV Range

10V Range

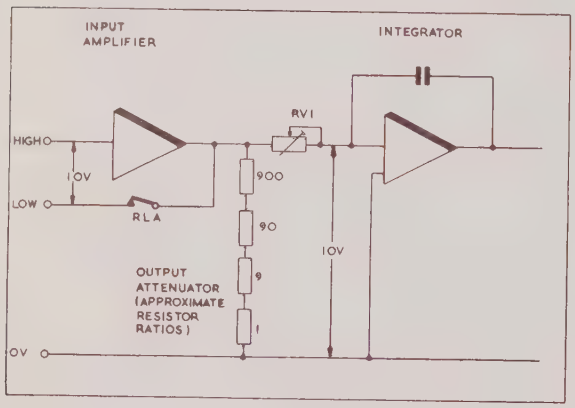


Figure 3.6 Input Amplifier - 10V Range

On the basic 10V range the input is applied as in figure 3.6. The amplifier will produce an output equal and opposite to the input voltage at which point equilibrium conditions are reached. The input amplifier thus has a gain of unity but presents a high impedance to the applied voltage [in the order of 10 GΩ]. The 10V amplifier output is applied to the integrator input via the calibration control RV1.

10mV Range

As shown in figure 3.7, the amplifier output voltage is attenuated in the ratio of 1000:1. To balance the 10mV input, therefore, the amplifier output must be 10 volts. Thus the same input as before is passed to the integrator. RV5 is the 10mV range calibration control.

100mV and 1V Ranges

For these two ranges, the amplifier output is attenuated in the ratios of 100:1 and 10:1 respectively and the same 10V input applied to the integrator when 100mV or 1V is present at the HIGH and LOW terminals. RV4 and RV2 provide calibration for the 100mV and 1V ranges respectively.

100V Range

Relays F and G switch in the 1000:1 input attenuator. An input of 100V is reduced to 100mV before being applied to the input amplifier whose gain is set to X100 as on the 100mV range. The integrator input is thus 10V.

1 000V Range

The 1000:1 input attenuator is again switched in by relays F and G. Input amplifier gain is set to X10 by RLB and an input of 1000V produces an integrator input of 10V as before.

Thermal emf Compensation

On each range one contact of either RLE or RLG is always in series with the input and any thermal voltages generated at the relay contacts will be added to the voltage to be measured. A second contact of either RLE or RLF is therefore connected in series with the LOW terminal producing an equal and opposite thermal emf to cancel out the first.

DC Filters

General

DC filtering is selected by the three position push button switch SE. Mechanical interlocking ensures that only one push button will remain depressed. A Field Effect Transistor [FET] protection circuit prevents possible damage to the input amplifier should none of the push buttons be pressed.

Out

With SE1 depressed input signals pass via VT1 to the input amplifier and the μV NOISE and 40 dB filters are switched out of circuit. If the current flowing into the input amplifier were excessive,damage could occur. With an input current of 1mA, however, the voltage across R17 is approximately +5 volts. MR2 conducts and, since the amplifier input is a virtual earth, VT1 gate will be held at +0.5 volt. The FET now operates in the constant current mode with drain current independent of drain/source voltage. Hence any increase in the applied voltage will not increase the input current above 1mA and no damage can be caused to the input amplifier. The FET is a bi-polar device with the drain/source functions completely interchangeable. Should the input current flow in the reverse direction, MR1 will conduct, biasing the gate negatively. VT1 will again operate in the constant current mode and limit input current to 1mA as before. VT1 is a 300 volt device and this voltage must not be exceeded at the input terminals unless the 1000:1 attenuator is in circuit i.e. on the 100V and 1000V ranges.

μV Noise

On the 10mV range, the maximum resolution is 1μV. At this level, amplifier noise can cause errors of the order of ±2 digits. SE2a and b connect C6 between the amplifier output and the LOW terminal stabilising unsteady readings on this range only.

40dB

The short circuit across R3 is removed when SE3a is depressed while closure of SE3b shorts out the FET protection circuit. One of the capacitors C1-C3 is connected between amplifier input and the LOW terminal via SE3a and appropriate range relay contacts and, with R3, forms a simple RC filter giving 20dB per decade attenuation. By using three separate filter capacitors the effects of di-electric charge storage, which could cause errors when switching to the most sensitive ranges, are reduced to an insignificant level.

Cal

The CAL push button SC isolates any signal voltages from the input amplifier and substitutes a Weston standard cell with an emf of approximately 1.0192 volts. Amplifier gain is set to X10 by the output attenuator and RV3 provides a fine control enabling the display to be set to the calibration figure on the front panel. The decimal point will remain in the position selected by range switch SH and should be ignored.

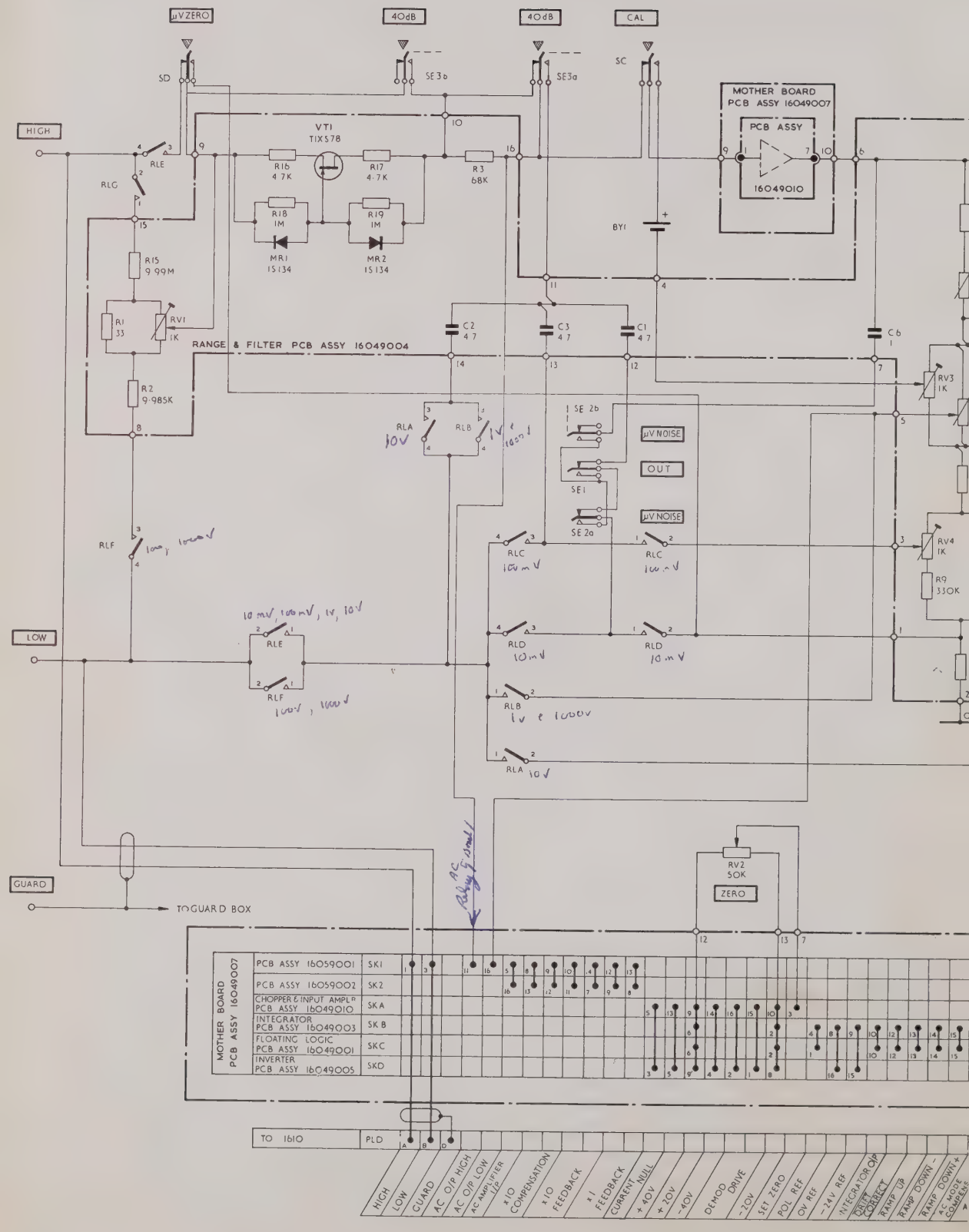
μV Zero

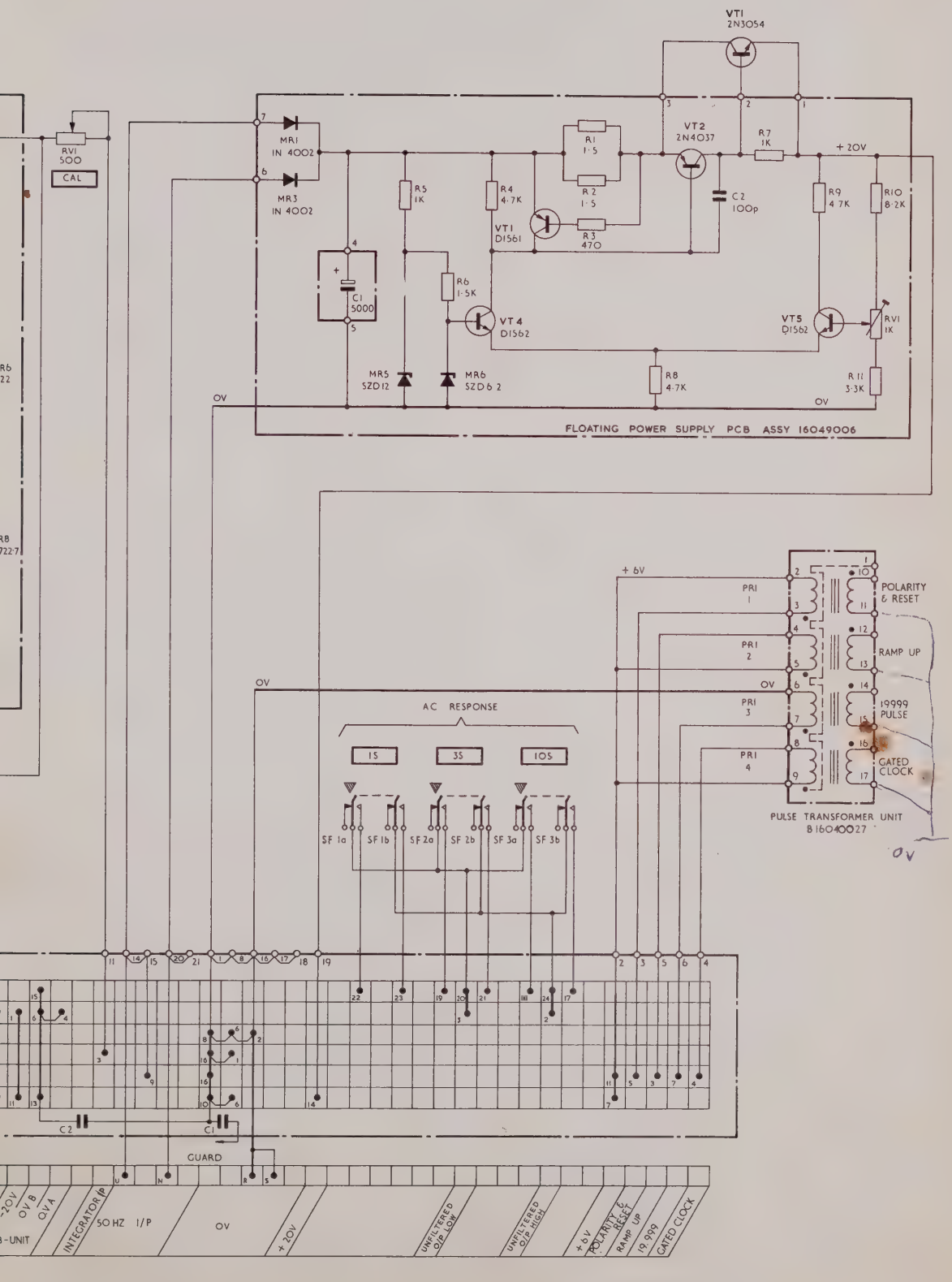
SD connects the amplifier input to R10. The voltmeter is thus automatically switched to the 10mV range with the input short-circuited. Front panel control RV2 which is connected between the ±20V rails, applies a positive or negative correction voltage to pin 3 on board 10 and should be adjusted to give a display of 0.000mV.

Floating Power Supply

The 50Hz low voltage output from T2 is coupled via plug PLD to pins 6 and 7 on the floating power supply board 6. This is a conventional series regulated supply with power transistor VT3 controlled by the differential amplifier VT4, VT5 via an amplifying stage VT2. Sampling chain R10, RV1 and R11 compares the +20 volt output with a reference voltage developed across zener diode MR6, any error voltage being applied to the base of VT2 and hence VT3. The +20 volt output is adjusted by RV1.

To avoid damage from overloading, VT1 samples the current drawn from the supply. If excessive, the voltage developed across R1 and R2 switches on VT1. The resultant positive potential applied to VT2 base via VT1 limits the available output current to approximately one amp.


µV ZERO
40dB
40dB
CAL
SD
SE3b
SE3a
SC
MOTHER BOARD
PCB ASSY 16049007
PCB ASSY
16049010
HIGH
VT1
TIXS78
RLE
RLG
R16
4.7K
R17
4.7K
R3
68K
R18
1M
R19
1M
MR1
1S134
MR2
1S134
BY1
R15
9.99M
R1
33
RV1
1K
R2
9.985K
RANGE & FILTER PCB ASSY 16049004
C2
4.7
C3
4.7
C1
4.7
C6
1
RV3
1K
RLA
RLB
SE2b
µV NOISE
OUT
SE1
SE2a
µV NOISE
RLF
RLC
RLC
RV4
1K
R9
330K
LOW
RLE
RLF
RLD
RLD
RLB
RLA
RV2
50K
ZERO
GUARD
TO GUARD BOX
MOTHER BOARD PCB ASSY 16049007
PCB ASSY 16059001 SK1
PCB ASSY 16059002 SK2
CHOPPER & INPUT AMPL PCB ASSY 16049010 SKA
INTEGRATOR PCB ASSY 16049003 SKB
FLOATING LOGIC PCB ASSY 16049001 SKC
INVERTER PCB ASSY 16049005 SKD
TO 1610 PLD
HIGH
LOW
GUARD
AC O/P HIGH
AC O/P LOW
AC AMPLIFIER I/P
+10 COMPENSATION
+10 FEEDBACK
+1 FEEDBACK
CURRENT NULL
+40V
+20V
-40V
DEMOD DRIVE
-20V
SET ZERO
POL REF
0V REF
-24V REF
INTEGRATOR O/P
ZERO CORRECT
RAMP UP
RAMP DOWN
RAMP DOWN
AC MODE COMPENS



01A 13 10 68

Floating Box

Board Nos 4, 6 and 7

D16047001 SHT 1 OF 2

INVERTER

The 20 volt output from the floating power supply is connected to the collectors of transistors VT1 and VT2 via the primary of the inverter transformer T1. The bases are supplied from the same source via R1 and T3 while the emitters are returned to the 0V rail via the other winding of T3. Since the bases are positive with respect to the emitters, one of the transistors, say VT1, will conduct. The resulting current flow through T3 primary induces an emf into the secondary which cuts off VT2 but increases the current flow through VT1 until T3 is saturated. At this point, the phase of the induced emf reverses and VT2 starts to conduct while VT1 cuts off. The process repeats generating a 30kHz square wave.

From T1 secondary windings are derived all supplies for the floating sections of the voltmeter i.e. floating logic, EX1605 a.c. unit, reference supply, input amplifier and integrator. After full wave rectification each rail is smoothed either by an RC filter in the case of low current supplies or by the LR filters where higher load currents flow. R43 prevents the $\pm$20 volt rails from rising above the working voltage of C14 and C15 when an a.c. unit is not fitted.

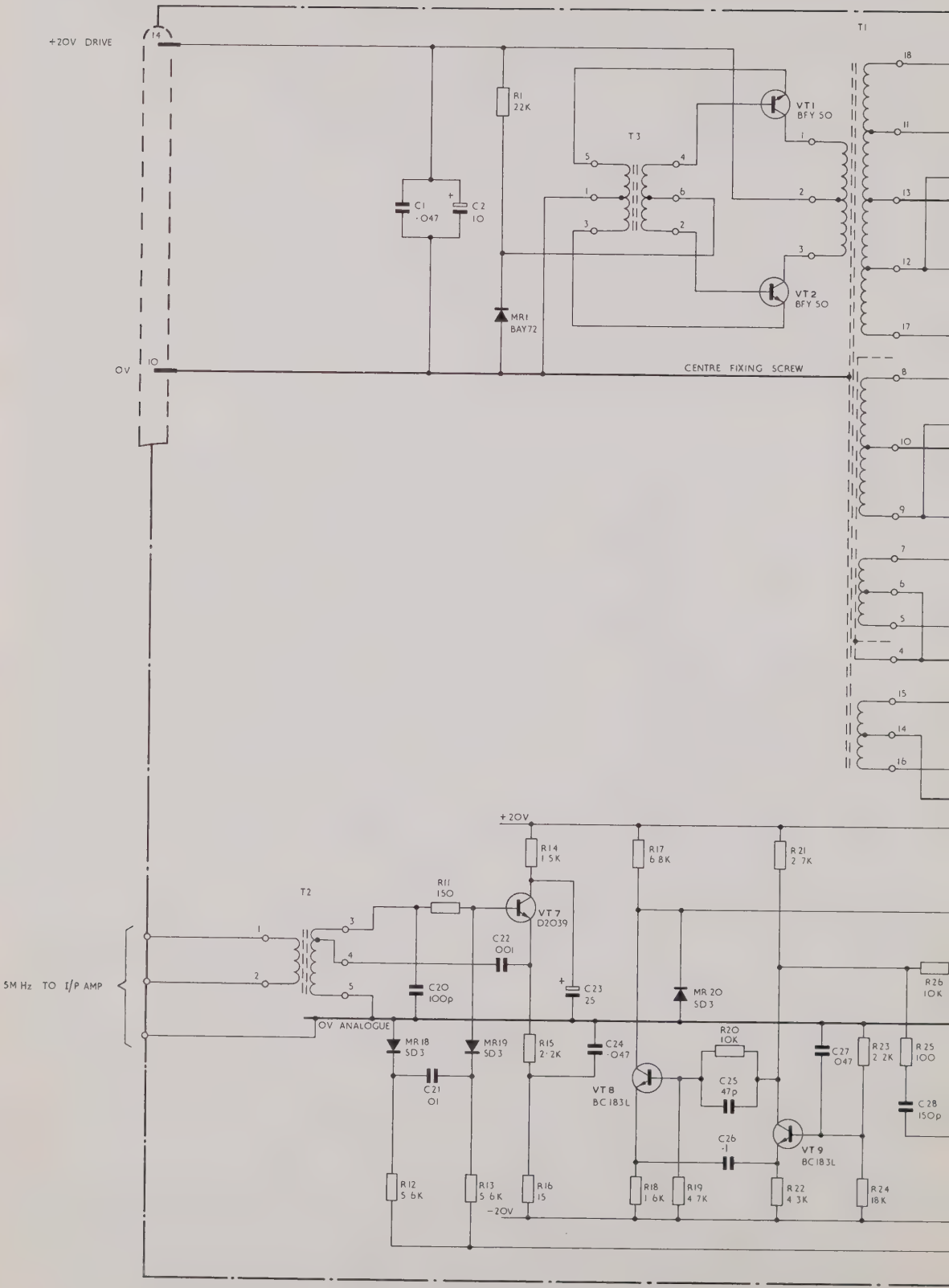
CHOPPER AC SUPPLIES

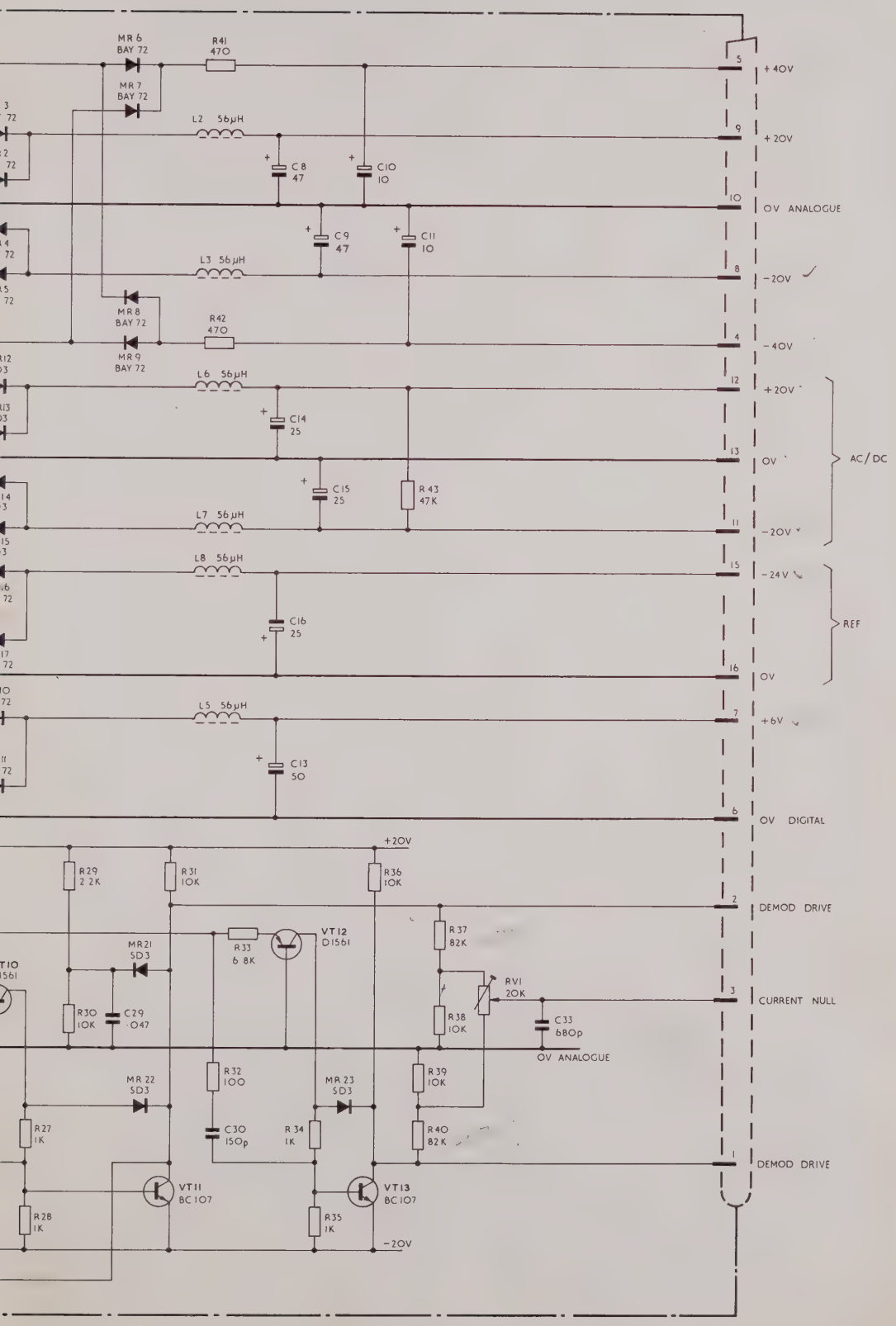
6kHz Multivibrator

VT8 and VT9 are connected as a 6kHz square-wave oscillator. Anti-phase outputs from the two collectors are passed via level changers VT10 and VT12 to the output stages VT11 and VT13 which supply drive to the FET demodulators in the input amplifier.
Resistor chains R37, R38 and R39, R40 together with RV1 provide an adjustable 6kHz square wave of either phase for current nulling purposes.

5MHz Oscillator

VT7 is a 5MHz oscillator with C20 and T2 primary defining the frequency of oscillation. When VT11 collector is negative, R12 and R13 are effectively connected across T2 primary and lower the Q to below the minimum required to sustain oscillation. A 5MHz oscillation 100% amplitude modulated at 6kHz will therefore be coupled into T2 secondary and the input amplifier chopper.


+20V DRIVE
14
T1
18
11
13
12
17
R1
22K
T3
VT1
BFY 50
C1
·047
C2
10
VT2
BFY 50
MR1
BAY72
0V
10
CENTRE FIXING SCREW
8
10
9
7
6
5
4
15
14
16
+20V
R14
1·5K
R17
6·8K
R21
2·7K
T2
R11
150
VT7
D2039
5MHz TO I/P AMP
C22
001
C20
100p
C23
25
MR20
SD3
R26
10K
0V ANALOGUE
MR18
SD3
MR19
SD3
R15
2·2K
C24
·047
R20
10K
C27
047
R23
2·2K
R25
100
C21
01
VT8
BC183L
C25
47p
C28
150p
C26
·1
VT9
BC183L
R12
5·6K
R13
5·6K
R16
15
R18
1·6K
R19
4·7K
R22
4·3K
R24
18K
−20V



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Chopper AC Supplies and Inverter

Board No.5

D16049305

INPUT AMPLIFIER

General

The input amplifier is a high gain, drift-corrected d.c. amplifier with a separate a.c. channel to extend the frequency response. Open loop gain falls at 20dB per decade from approximately 170dB at d.c. to unity at 5MHz. The input attenuator limits the closed loop gain to a maximum of 60dB as described in the section 'Input Amplifier Switching'.

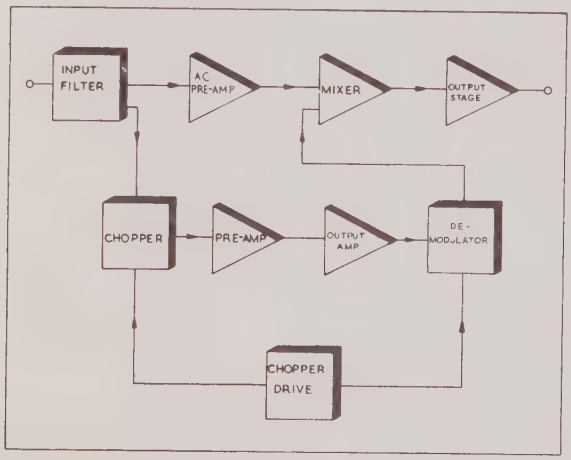


Figure 3.8 Input Amplifier - Block Diagram

Figure 3.8 is a block schematic diagram of the complete amplifier with figure 3.9 illustrating the frequency response.

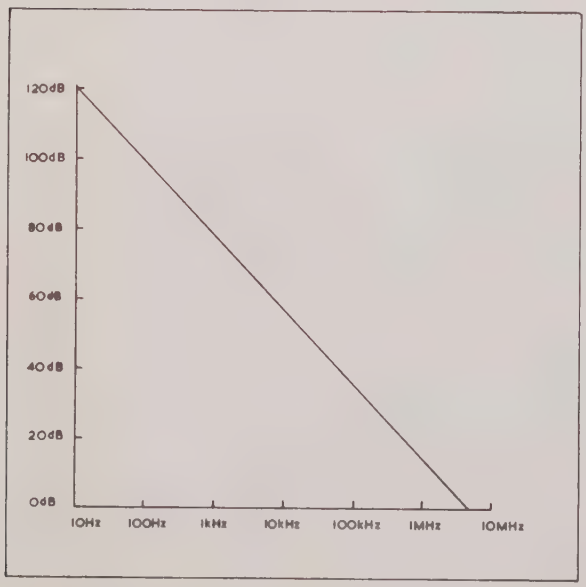


Figure 3.9 Input Amplifier - Frequency Response

Chopper

The chopper driving waveform from the 5MHz sine-wave oscillator is applied to pins 6 and 7 of T1. When the chopper conducts, R23, VT1 and R26 provide a low impedance path between the amplifier input and 0 volts. Any 6kHz drive to the base and collector of VT1 - if referred to 0 volts - would be coupled via the base/emitter or collector/emitter capacitances to generate an input indistinguishable by the amplifier from a genuine signal input. Chopper drive is therefore taken from the floating secondary of transformer T1 which is isolated from earth. The use of a 5MHz carrier permits the use of low inductance windings for T1 having negligible interwinding capacitance thus further enhancing 8kHz rejection. The 5MHz carrier is filtered out by R1, C1 leaving the 6kHz envelope to be applied to VT1 base via the bi-filar winding L1 which provides further 5MHz rejection.

D.C. Offset

The characteristic of the double emitter chopper transistor VT1 is such that, when conducting, both emitters remain typically within 50μV of each other and a potential applied to emitter No.2 [board 13, pin 2] will control the voltage on emitter No.1. Thus a d.c. offset occurring on emitter No.1 can be reduced to zero by applying a voltage of the required polarity via resistor chain R38, R31 and R26 to emitter No.2.

Temperature Compensation

Since changes of temperature will cause a variation in offset voltage of approximately 1μV per ^{o}C and since, on the 10mV range, the voltmeter resolution is 1μV, it is necessary to provide temperature compensation at emitter No.2. The temperature coefficient of diodes MR14 and MR15 is approximately 2.5mV per ^{o}C which is reduced to the required 1μV per ^{o}C by RV2 and resistor chain R13, R26. By connecting the diodes in opposite sense, either positive or negative correction is available as required.

Spike Reduction

Figure 3.10 shows the main circuit capacitances associated with the chopper transistor which form a bridge.

To prevent chopper spikes from being passed into the pre-amplifier, the bridge must be balanced by adjustment of C13. CE1 and CE2 will vary with temperature by the same amount but since the capacitance RATIOS in the bridge remain constant, the balance is unaffected by temperature variations.

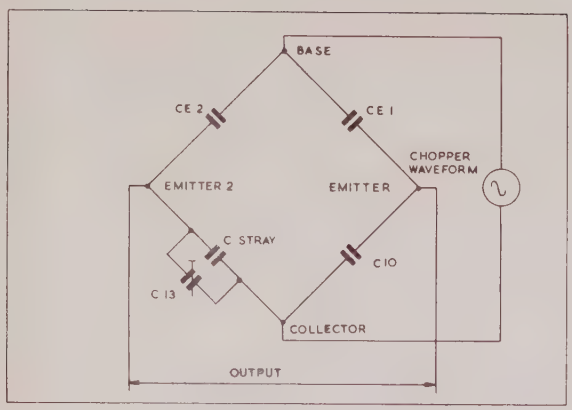


Figure 3.10 Spike Reduction - Chopper Bridge Circuit

Chopper Channel Pre-amplifier

The pre-amplifier and chopper are contained in a screened box connected to 0V.

The d.c. input is applied to terminal 1 on Board 10 and is chopped to the 0V rail via R2, R23, VT1 and R10. VT5 and VT6 are a feed-back pair with a gain of 20 - noise being reduced to a low level by running VT5 at a low collector current.

Chopper Channel Output Stage

The pre-amplifier output is applied to the base of VT9 which, together with VT10 forms a differential amplifier. Demodulators VT14 and VT15 are driven in anti-phase by the 6kHz multivibrator on board 5.

The phasing is such that VT15 is switched on when the chopper transistor, VT1, is cut off. During this period, the voltage being measured is connected to VT5 base and amplified before being applied to VT9. The consequent output developed at VT12 collector is fed back to VT10 base via VT15.

Since VT9 and 10 are a differential amplifier, a balanced condition will occur when the current flowing into C17 reaches zero. At this point, the voltage on VT10 base is approximately equal to that on VT9 base. The voltage stored on C17, however, is composed of both signal and an amplifier drift component.

When VT1 shorts the d.c. input to 0 volts VT15 is switched off and VT14 on. The differential amplifier is unbalanced and the stored voltage on C17 amplified and fed via VT14 to the mixer stage. The drift component stored with the signal cancels any drift now occurring in the output amplifier.

Current Zero

When the chopper transistor switches on, the current drawn from the input source introduces a 6kHz component into the input amplifier. A small 6kHz voltage is therefore fed into the output stage of the d.c. amplifier via R44 to cancel this offset. The current null control RV1 on board 5 is connected across the attenuated anti-phase 6kHz demodulating outputs and is set during factory tests to reduce input current to zero.

A.C. Pre-amplifier

The a.c. pre-amplifier consisting of VT1 and VT2 starts to become effective at approximately 1Hz with crossover between a.c. and d.c. channels occurring at 300Hz. The use of an FET input stage minimises noise fed back to the d.c. channel. VT2 output is coupled via C4 and R18 to the base of VT4.

Mixer

The output from the d.c. channel on VT3 base is mixed with the a.c. channel output on VT4 base and the resultant signal at VT3 collector amplified by VT7 and VT8 before being applied to the base of VT16 in the output stage.

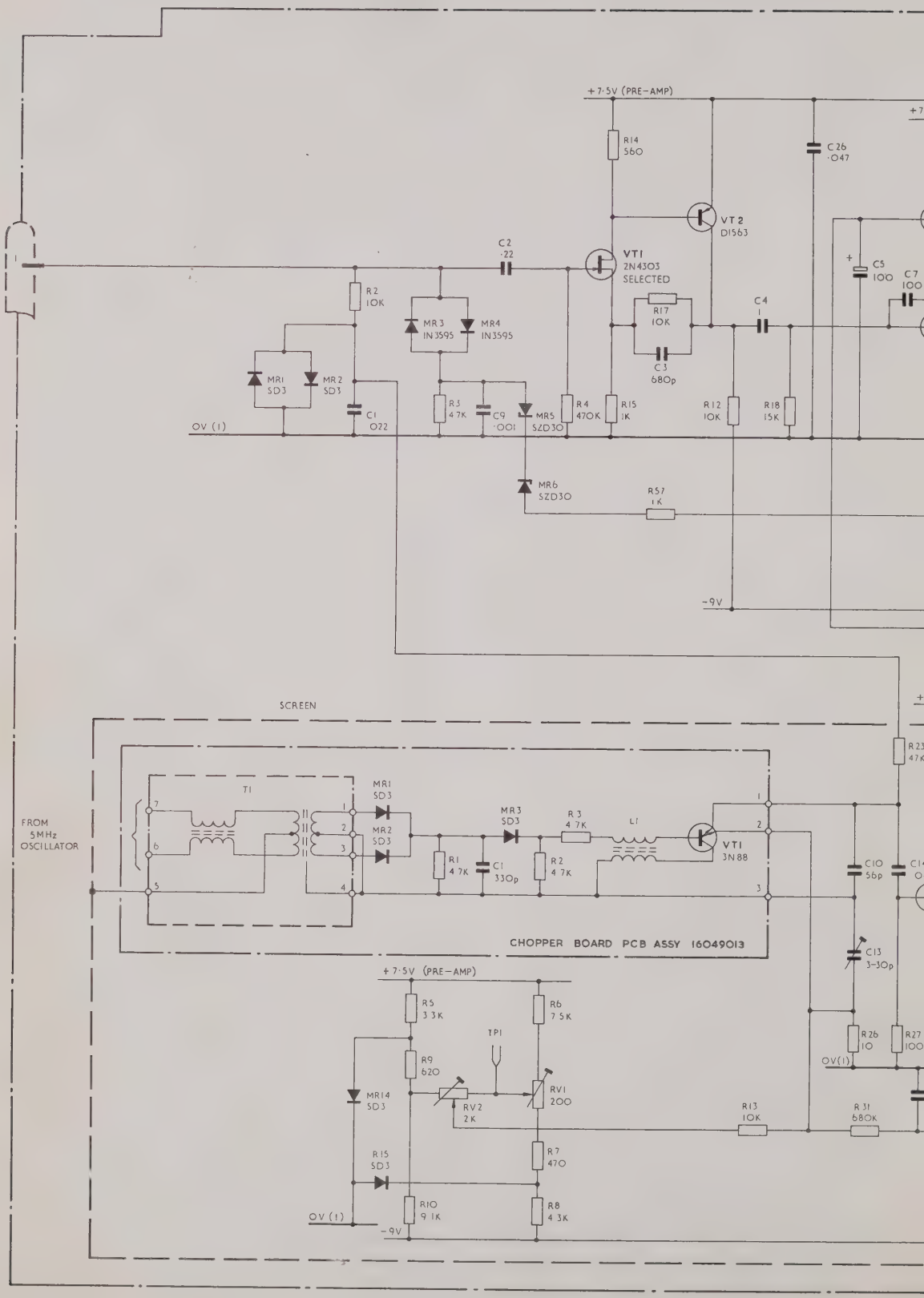
Output Stage

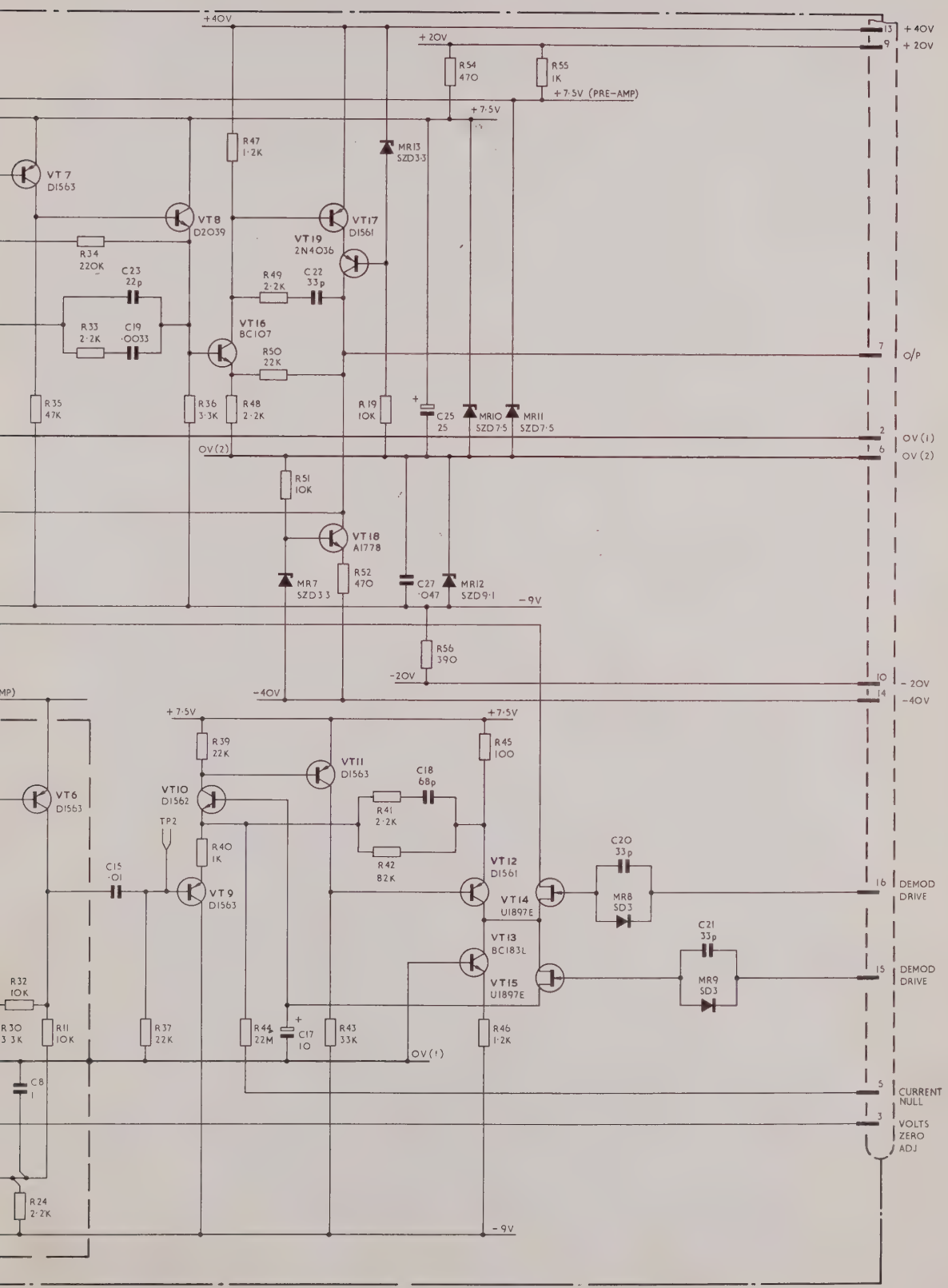
The output stage is a X10 amplifier with 40 volt end stops. However, if the voltmeter input were allowed to drive the amplifier to these limits overloading would occur which, because of the amplifier recovery time, would either restrict the speed of operation or produce errors for several readings following the removal of the overload. A protection circuit is therefore incorporated to limit the output swing to $\pm$30 volts. Since, for a full scale reading, the integrator requires an input of approximately $\pm$20 volts, this still allows the input amplifier to accept input signals which will produce up to 10 volts series mode interference at its output before the overload circuit comes into effect.

Overload Protection

Should the voltage on pin 7 tend to increase beyond $\pm$30 volts, either MR5 or MR6 will come into operation and, by effectively connecting output to input, limit the amplifier gain to unity.

Protection of the d.c. channel is provided by MR1 and MR2 which limit the voltage applied to VT1 emitter to a safe value.


+7·5V (PRE-AMP)
R14 560
C26 ·047
VT2 D1563
C2 ·22
VT1 2N4303 SELECTED
C5 100
C7 100
R2 10K
MR3 IN3595
MR4 IN3595
R17 10K
C4
C3 680p
MR1 SD3
MR2 SD3
C1 022
R3 4·7K
C9 ·001
MR5 SZD30
R4 47OK
R15 1K
R12 10K
R18 15K
OV (1)
MR6 SZD30
R57 1K
-9V
SCREEN
FROM 5MHz OSCILLATOR
T1
MR1 SD3
MR2 SD3
MR3 SD3
R3 4·7K
L1
R1 4·7K
C1 330p
R2 4·7K
VT1 3N88
C10 56p
CHOPPER BOARD PCB ASSY 16049013
C13 3-30p
+7·5V (PRE-AMP)
R5 3·3K
R6 7·5K
TP1
R9 620
RV1 200
RV2 2K
MR14 SD3
R13 10K
R31 680K
R26 10
OV(1)
R7 470
R15 SD3
R10 9·1K
R8 4·3K
OV (1)
-9V



02 3.9.69.

Input Amplifier and Chopper

Board Nos 10 and 13

D16049310

LOGIC CONVENTIONS

Throughout the ensuing descriptions, the following conventions are used
HIGH signifies +5 volts or a logical 1
LOW signifies 0 volts or a logical 0.

INTEGRATOR AND REFERENCE SUPPLY

Reference Supply

General

The reference supply is derived from a zener diode MR3 which is contained in a temperature controlled oven and supplied with a constant current.
The supply is floating and by connecting one side or the other to the 0V rail a +9V or -9V reference can be obtained.

Constant Current Supply

The -24 volt reference rail is applied via series transistor VT4 to the junction of R4 and R7. The voltage at this point is sampled by the resistor chain R7, R8 and compared with the voltage across zener diode MR3 by the differential amplifier VT2, VT3. A balanced condition will be reached with the bases of both these transistors held at -9 volts and VT4 collector at -18 volts. The sampling resistor chain will detect any variation of the 18 volts and a correction will be applied to the base of VT4. MR3 is thus supplied from a stabilised 18 volt source and zener current will be constant, fixed by R4 at 7.5mA.

R69 supplies MR3 from the -24 volt rail should VT4 be cut off by a 'lock-out' condition occurring on switching on the voltmeter. C1, by reducing a.c. gain to a low value, minimises any tendency for the circuit to oscillate.

Thermal Feedback Amplifier

VT23, VT22 and VT1 are a three stage d.c. amplifier. Overall negative feedback is applied thermally by enclosing VT23 in the heat sink on which power transistor VT1 is mounted - any increase in VT1 collector current raising the temperature of the heat sink and increasing VT23 collector current. A d.c. input from RV3 determines the final heat sink temperature which is set and maintained accurately at 65°C. Thus, the reference zener MR3, which is also enclosed in the heat sink, operates at a constant temperature.

Integrator

General

The ±20V full scale output from the input amplifier is applied to edge connector pin 3. R9-R15 provide a coarse adjustment set up during factory tests to reduce this to ±5V.

The integrating amplifier consists of VT18a and b and IC1. IC2 operates as a switch controlling VT21 whose output is used to operate logic circuitry concerned with polarity decisions and the ramp down bistable.

The integrator operation is controlled by four transistor switching circuits driven from the floating logic circuitry on board 1. The timing of the relevant control waveforms is illustrated in figure 3.4. A full description of the logic operation is given in the section 'Floating Logic'.

Ramp Up

A LOW indicating ramp up is applied to edge connector pin 13. VT10 and VT11 are a fast non-saturating switch with MR7 preventing VT11 from bottoming. The ramp up signal switches on VT10 and VT11 and a positive potential is applied to VT5 gate via MR4. VT5 switches on to connect the attenuated output from the input amplifier to the integrating resistor R20. MR4 prevents the flow of gate current when VT5 is on and C2 provides a charge for gate capacitance.

The integrator output will now rise at a rate dependent upon the integration components R20, C11 and the amplitude of the input voltage. According to the polarity of the input the ramp applied to IC2 pin 4 will be either positive or negative-going. If a positive voltage is applied to the voltmeter terminals then, following inversion by the input amplifier, the integrator input will be negative. IC2 input will thus be a positive ramp. Conversely, when measuring a negative voltage, the integrator applies a negative ramp to IC2.

IC2 is a comparator with a gain of approximately 1 000. When the integrator output is zero, IC2 output settles to +1.5 volts. When an input is applied to the integrator at the beginning of ramp up IC2 swings hard over to an end stop as shown in figure 3.11, where it will remain until the integrator output passes through zero during ramp down.

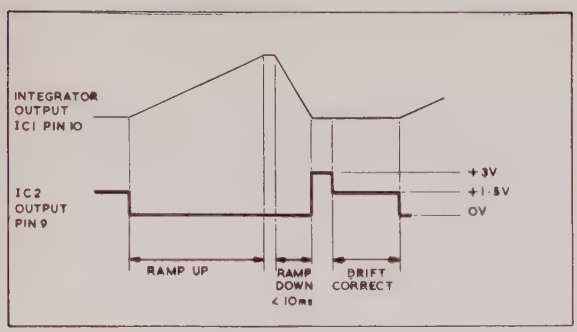


Figure 3.11 Detector Output - Positive Ramp Up

At this point, IC2 will switch to the other polarity end stop, generating a positive-going edge which will be applied to VT21 base.

If, as in figure 3.12, the integrator output rises positively, the detector operates as shown applying a negative-going edge to VT21.

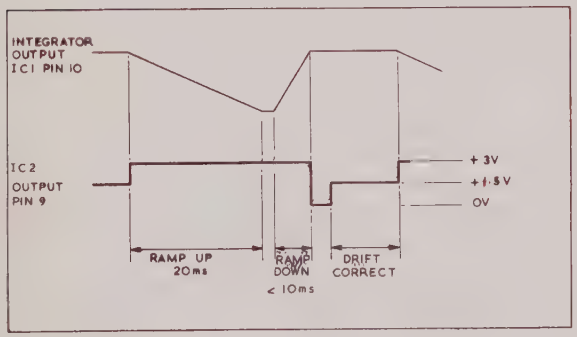


Figure 3.12 Detector Output - Negative Ramp Up

VT21 output is passed to the logic circuitry on board 1 and, at the end of the ramp up period, is used to decide polarity - a HIGH at edge connector pin 10 indicating a positive polarity input voltage and vice-versa. The polarity decision can not be taken earlier since, as figure 3.13 shows, the integrator output can swing through zero if series mode interference is present on the input voltage applied to the input terminals.

As the ramp up period of 20msec is locked to the mains frequency, interference voltages at 50Hz and its harmonics will produce no output from the integrator since the integral of a sine wave over one complete cycle is zero.

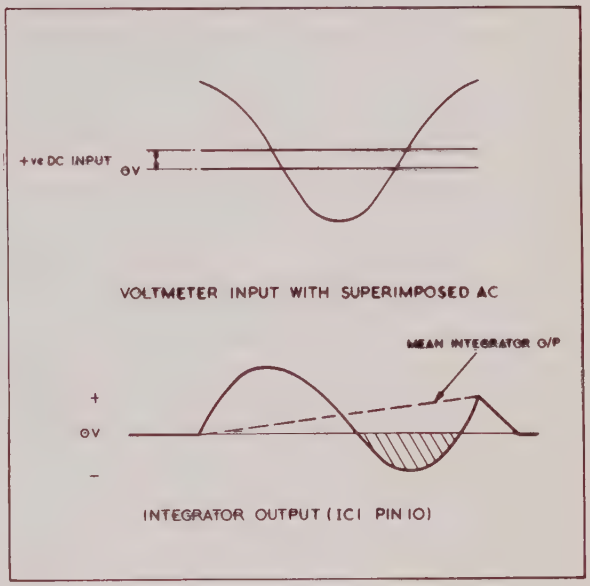


Figure 3.13 Integrator waveform with 50Hz Interference

At the end of ramp up, a HIGH is applied to edge connector pin 13 switching off VT10 and VT11 and hence VT5 to remove the integrator input.

Delay

When the polarity decision based on information from the integrator has been taken by the logic circuitry on board 1, an appropriate signal is passed via edge connector pin 4 to the bases of VT8 and VT9. Should the final ramp up voltage from the integrator be positive, a LOW on pin 4 switches on VT8 which connects MR3 anode to 0 volts. VT9 is switched off and VT7 source is returned to MR3 cathode which now stands at +9 volts.

A negative integrator ramp up voltage produces a HIGH at pin 4. VT9 now switches on and earths MR3 cathode while VT8 - being switched off - allows MR3 anode and hence VT6 drain to rise to -9 volts.

Ramp Down

Ramp down information is applied via edge connector pins 14 and 15 to VT6 and VT7 gates via transistor switches having a fast cut-on characteristic. The slower switch-off capability caused by VT13 and VT15 bottoming is unimportant. If the final integrator voltage is positive [when a negative input has been integrated] a LOW will be applied to pin 15. VT14 and VT15 switch on and the +20 volts at VT15 collector switches on VT7 via MR6 to apply the +9 volt reference voltage to RV2 and the integrator input. Ramp down now commences and the integrator output falls negatively towards zero at which point IC2 switches as in figure 3.11. VT21 conducts and a negative-going edge is passed to the logic circuitry to terminate the ramp down period.

A negative voltage stored on C11 during ramp up will cause a LOW to be applied to edge connector pin 14. VT6 will switch on and the integrator input will be -9 volts derived from MR3 anode via VT6 and R64. The integrator output rises towards zero at which point the negative-going edge shown in figure 3.12 is developed by IC2 to switch off VT21 and thus applying a positive-going edge to pin 10. The logic circuitry on board 1 again recognises that the integrator output has reached zero and terminates ramp down.

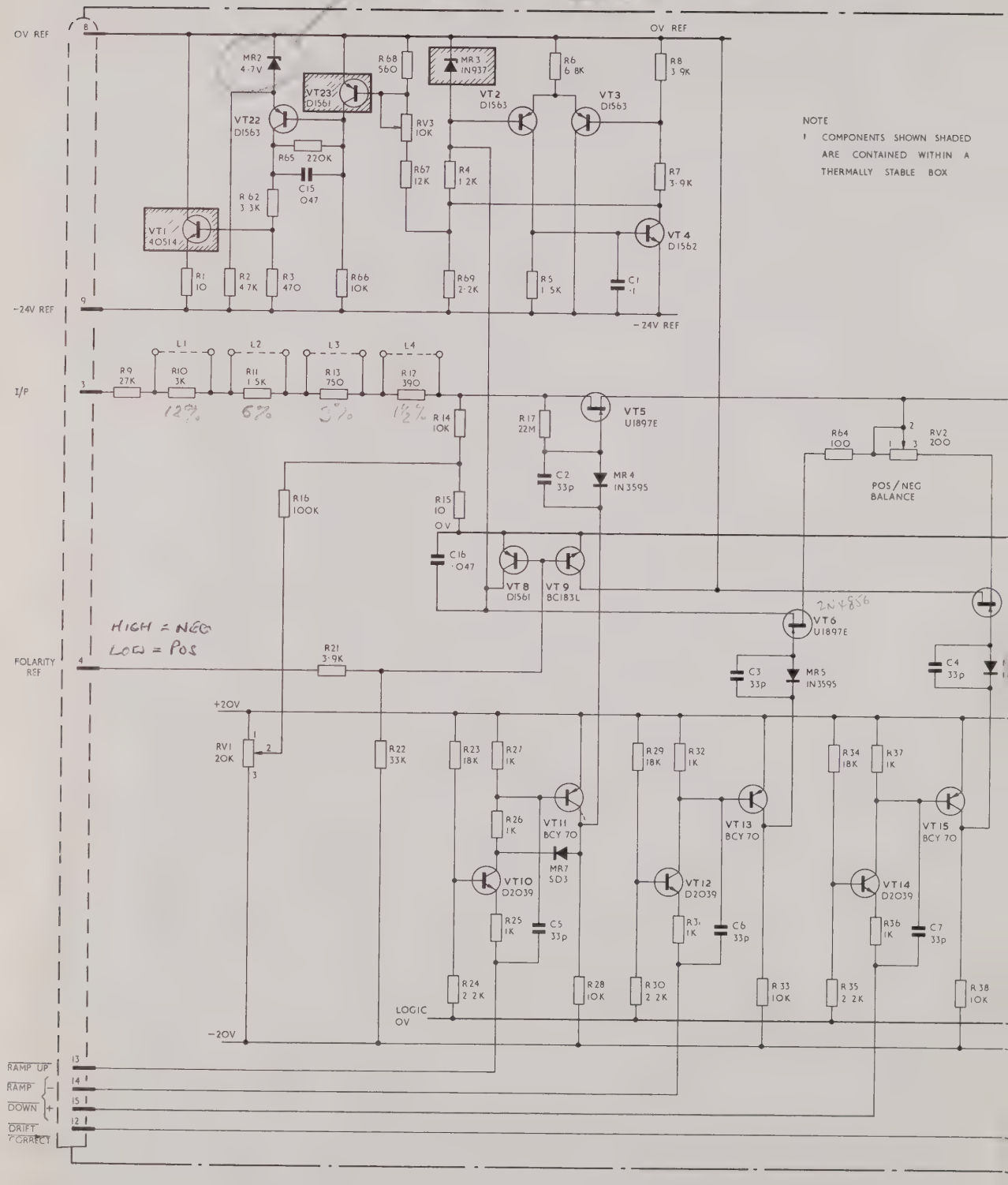
To allow for differences in the characteristics of VT6-VT7 a balance control RV2, is adjusted during factory tests to equalize positive and negative integration rates during ramp down.

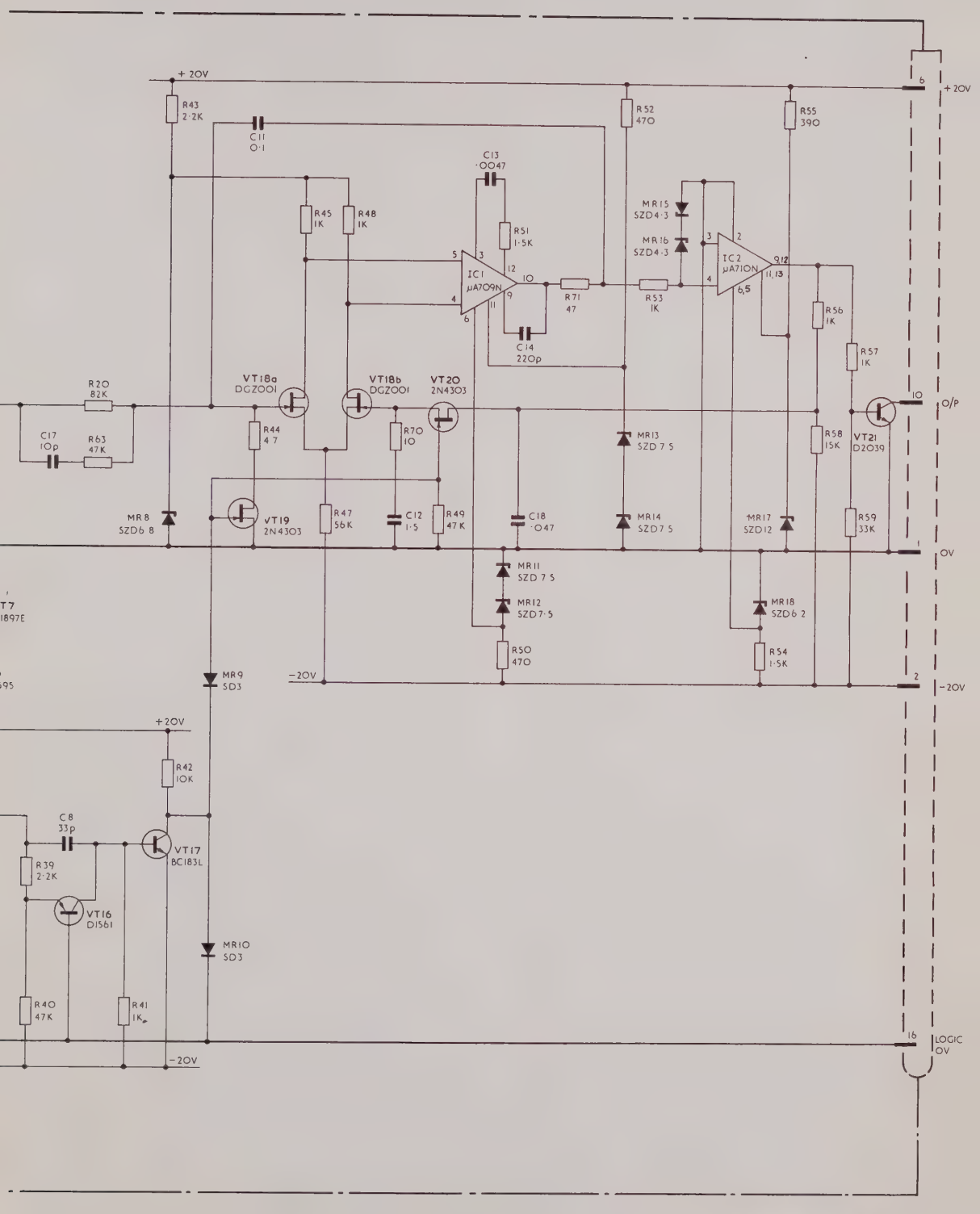
Drift Correct

It is imperative that integration always start from zero for measuring accuracy to be maintained. The drift correct period makes certain that this is the case by ensuring that the integration capacitor C11 is fully discharged before the next ramp up period begins. At the same time a drift correction voltage is stored on C12.

A LOW signifying drift correct is applied to edge connector pin 12 causing VT16 and VT17 to switch off. VT17 collector rises to approximately +0.5 volt, as determined by MR10, switching on VT19 and VT20 via MR9. VT18a gate is now returned to 0 volts via R44 and VT19. A balancing process ensues during which the amplifier drift voltage is stored on C12. IC2 output [pin 9] will stabilize at approximately +1.5 volts and its input [pin 4] at 0 volts. When VT19 and VT20 are switched off at the end of the drift correct period and ramp up commences, the inputs to the differential amplifier VT18a and b will be a signal voltage from the input amplifier and the drift correction voltage stored on C12.

Errors introduced by transients generated when VT17 is switched on at the end of drift correct are offset by the small positive or negative bias derived from RV1 and applied in series with the signal input.


OV REF
-24V REF
I/P
POLARITY REF
RAMP UP
RAMP DOWN
DRIFT CORRECT
MR2 4·7V
MR3 IN937
VT23 D1561
VT22 D1563
VT1 40514
VT2 D1563
VT3 D1563
VT4 D1562
VT5 U1897E
VT6 U1897E
VT8 D1561
VT9 BC183L
VT10 D2039
VT11 BCY 70
VT12 D2039
VT13 BCY 70
VT14 D2039
VT15 BCY 70
MR4 IN3595
MR5 IN3595
MR7 SD3
R1 10
R2 4·7K
R3 470
R4 1·2K
R5 1·5K
R6 6·8K
R7 3·9K
R8 3·9K
R9 27K
R10 3K
R11 1·5K
R13 750
R12 390
12%
6%
5%
1½%
R14 10K
R15 10
R16 100K
R17 22M
R21 3·9K
R22 33K
R23 18K
R24 2·2K
R25 1K
R26 1K
R27 1K
R28 10K
R29 18K
R30 2·2K
R31 1K
R32 1K
R33 10K
R34 18K
R35 2·2K
R36 1K
R37 1K
R38 10K
R62 3·3K
R64 100
R65 220K
R66 10K
R67 12K
R68 560
RV1 20K
RV2 200
RV3 10K
C1 ·1
C2 33p
C3 33p
C4 33p
C5 33p
C6 33p
C7 33p
C15 ·047
C16 ·047
L1
L2
L3
L4
+20V
-20V
LOGIC OV
POS/NEG BALANCE
HIGH = NEG
LOW = POS
2N4856
NOTE
1 COMPONENTS SHOWN SHADED ARE CONTAINED WITHIN A THERMALLY STABLE BOX



02 39.69

Integrator and Reference Supply

Board No. 3

D 16049303

FLOATING LOGIC

General

A 50Hz voltage initiates the logic sequence described in section 'Principles of Operation' to control the operation of the integrator. Clock pulses and polarity decisions are also passed to the counters and display circuitry. By using pulse transformers for coupling, direct connection between the input circuits [i.e. input amplifier and integrator] and the earthy output circuitry [i.e. display and fan-out units] is avoided thus enabling a high insulation impedance to be maintained between the two.

2MHz Clock Oscillator

The voltage controlled oscillator VT6, VT7 and VT8 generates 2MHz pulses. A manual adjustment to the frequency of oscillation is achieved by means of RV1 which varies the potential at the base of emitter follower VT5 and hence VT6 base. The charge held on C10 and applied via VT3, VT4 and R31 to VT5 also provides a control of frequency. By charging C10 either positively or negatively, the frequency can be increased or reduced as necessary.

2MHz Gate

The nominal 2MHz pulses after amplification and double inversion by VT9 and IC11c are fed to the counter via NAND gate IC11d and edge connector pin 4 or, when IC11d is closed, via bistable IC12 and inverter IC11b. In the latter case, IC12 divides by two and pulses at 1MHz pass into the counter. IC11c also supplies clock pulses to operate the ramp up and ramp down bistables IC7 and IC4.

50Hz Squarer

A 50Hz voltage is applied to edge connector pin 9 and is squared by VT1 and VT2. R55 and C15, by filtering out mains spikes, prevent spurious triggering of the squarer. The squarer output is arranged to be asymmetrical as explained in the section 'Drift Correct'.

25Hz Bistable

The negative-going edges of the 50Hz square wave output from VT2 collector trigger bistable IC8 to provide antiphase 25Hz outputs at pins 6 and 9.

Ramp Up Bistable

IC6a input is held HIGH by resistors R7 and R8 in the absence of 25Hz triggering pulses. The ramp up bistable IC7 is thus inhibited since both its steering gate inputs are LOW.

When the output on pin 9 of IC8 changes from a HIGH to a LOW, the differentiating circuit C4, R7 and R8 applies a 10μsec negative-going pulse to IC6a. The consequent HIGH on IC7 pin 12 allows the ramp up bistable to be turned over by the next 2MHz clock pulse to arrive from IC11c. IC7 remains in this, the set condition, since the permanent LOW on pin 4 prevents any further bistable action due to clock pulses. IC7 pin 9 now changes to a HIGH removing an inhibit from pin 10 of IC12. The 1MHz bistable thus operates on each negative-going clock pulse edge and passes 1MHz pulses to edge connector pin 4. Since both steering inputs to the ramp down bistable are LOW, IC4 pin 6 remains HIGH. After inversion by IC3c, this is applied as a LOW to IC11d which is inhibited.

'Ramp up in progress', information is supplied to the earthy logic circuitry from IC7 pin 9 via edge connector pin 3 and to the integrator series input FET from IC7 pin 6 via edge connector pin 13.

1MHz clock pulses are accumulated by the counter circuits until a count of 19999 has been reached after a nominal 20msec. at which point a positive-going pulse is applied to VT10 base via edge connector pin 7. The LOW generated at VT10 collector resets the ramp up bistable. The 2MHz clock pulses on IC7 pin 2, however, can not now toggle the bistable since IC6a output has returned to a LOW and closed the input gate.

Delay Monostable

On being reset, IC7 pin 9 changes from HIGH to LOW and the negative-going pulse from the differentiating circuit C5, R12 and R13 starts the 33μsec. delay monostable, IC6b, IC6d. The positive-going edge applied to IC5a by differentiating circuit C6, R16 and R17 at the commencement of the monostable period has no effect. After the delay period when IC6b output falls negatively, however, a HIGH is applied by IC5a to the ramp down bistable IC4.

During the delay period, IC12, the 1MHz bistable, is inhibited by the LOW from IC7 pin 9. Also, the ramp down bistable applies a HIGH to IC3c whose LOW output inhibits IC11d. Thus neither 1MHz nor 2MHz clock pulses can accumulate in the counters.

Ramp Down Bistable

The next 2MHz clock pulse at IC4 pin 2 sets the bistable such that the output on pin 6 is LOW with pin 9 HIGH.

IC3c now provides one HIGH input to NAND gate IC11d which permits 2MHz clock pulses to pass from IC11c to edge connector pin 4. IC12 no long applies 1MHz pulses to IC11b as the LOW on pin 10, derived from the ramp up bistable, holds IC12 in the reset condition.

Polarity Decisions

During ramp up, the integrator output may assume either polarity. The final ramp up voltage is sensed and a detector applies a HIGH or LOW, as appropriate, to edge connector pin 10.

Assume a LOW [indicating a negative polarity stored on the integrator capacitor] is present on pin 10 at the end of ramp up. The LOW on IC2c pin 10 closes that gate to apply a HIGH to IC1a pin 2. IC2a inverts the LOW and supplies a HIGH to IC2b pin 4. When, at the end of ramp up, the potential on pin 9 of the ramp up bistable changes from HIGH to LOW, the negative 10μsec pulse passed by the differentiating circuit C17, R50 and R51 to IC13d causes a HIGH to be applied to the second inputs of NAND gates IC2b and IC2c. The former opens and a LOW is fed to IC1b. The polarity bistable IC1b, IC1a is thus set such that pin 6 is HIGH and pin 3 LOW.

These levels are passed to NAND gates IC3a and IC3b. Subsequently, when, at the commencement of ramp down, IC4 applies a HIGH to both gates, IC3a opens and feeds a LOW to edge connector pin 14. Further, IC1b output is also passed to edge connector pin 1. These two outputs select the appropriate sense reference voltage to be applied to the integrator during ramp down as described in the section 'Integrator and Reference Supply'. In this case, it will be seen that the HIGH on edge connector pin 1 switches on VT9 on board 3 connecting the 0V ref. rail to 0 volts. The -9 volt rail is connected to the integrator input when the LOW on edge connector pin 14 board 1 switches on VT6 via VT12 and VT13. Since we have assumed a negative voltage to be held on the integrator capacitor, this negative input will now ramp the integrator output up to zero volts.

Had a positive voltage been retained by the integrator after ramp up, then the HIGH passed by the detector to board 1 pin 10 would, by similar reasoning, produce a LOW at edge connector pin 1. NAND gate IC3b would be opened to feed a LOW to pin 15 while IC3a would remain closed holding pin 14 HIGH.

Termination of Ramp Down

When, during ramp down, the integrator output reaches zero, the detector switches as described in the section 'Integrator and Reference Supply', applying a positive or negative-going edge to board 1 pin 10.

Still assuming a negative integrator voltage stored during ramp up, then the detector feeds a HIGH to edge connector pin 10 on board 1. This input does not affect the polarity bistable IC1a and b since IC13d is holding pins 5 and 9 of the input gates LOW. The LOW on pin 9 of IC1c inhibits that gate producing a HIGH at its output. IC1d has a HIGH on pin 13 and a LOW on pin 12 from the polarity bistable. IC1d is therefore inhibited and its HIGH output supplies a second input to IC2d which opens. The LOW from IC2d applied to IC4 pin 10 resets the ramp down bistable and ramp down ceases.

If we now assume that the integrator output rose in a positive direction during ramp up then the polarity bistable will have been set such that pin 10 of IC1c is LOW inhibiting that gate, while IC1d pin 12 is HIGH. The LOW applied to edge connector pin 10 when the detector senses zero has been reached now inhibits IC1d. IC2d again has two HIGH inputs and supplies a reset signal to the ramp down bistable.

If, as in overload conditions, the integrator output does not reach zero in 10msec. an alternative method of resetting the ramp down bistable is employed. Since 2MHz pulses are accumulated by the counter during ramp down, a count of 19999 is reached in a nominal 10msec. VT10 thus issues a second pulse which, following double inversion by IC5b and c, resets the ramp down bistable.

When reset, IC4 inhibits IC11d via IC3c. As the 1MHz bistable IC12 is inhibited by the ramp up bistable, no further pulses - either 1MHz or 2MHz - can be passed to the counters until the commencement of the next ramp up period.

Drift Correct

The voltages at VT2 collector and pin 9 of the 25Hz bistable are compared by NAND gate IC10d which generates a LOW output for approximately 10msec.

From figure 3.4 it will be apparent that the drift correct period must be less than 10msec in order to restrict the time for one complete measurement cycle to 40msec.

To this end, the negative bias applied to VT1 base via R57, ensures that the squarer output is asymmetrical. The drift correct waveform of figure 3.14, therefore, lasts for less than 10msec, and is typically 9msec.

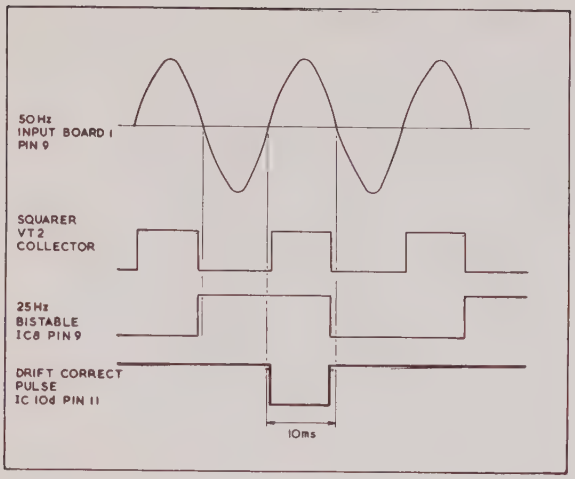


Figure 3.14 Drift Correct Waveform

Clock Frequency Adjustment

In the interests of maintaining the maximum possible series mode rejection the ramp up period or integration time must be locked to the mains frequency. This is achieved by comparing the ramp up period with an output from the 25Hz bistable, any timing discrepancy modifying the frequency of the 2MHz oscillator and hence the ramp up period.

It is essential for the sake of accuracy that any correction be applied to the clock after ramp up and ramp down have been completed - adjustment actually being carried out during the drift correct period.

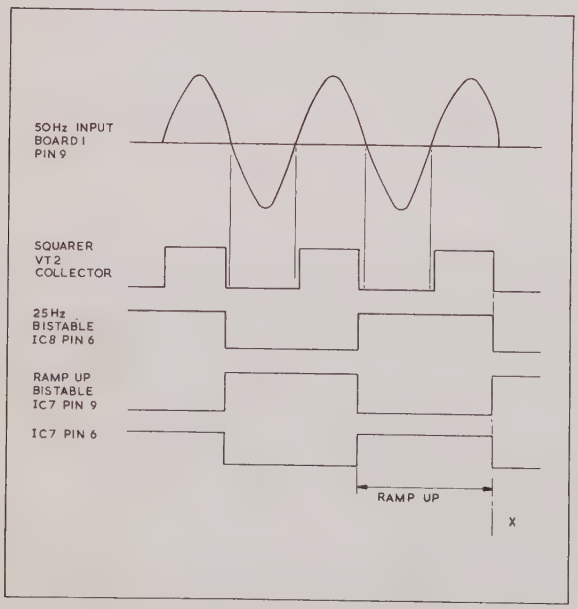


Figure 3.15 Clock Frequency Adjustment

Figure 3.15 shows the relevant waveforms associated with frequency adjustment.

Suppose that ramp up ends after time X. The frequency adjust bistable IC9 will be toggled by the negative-going edge from IC8, with the HIGH from IC7 pin 9 steering the outputs at pins 6 and 9 to LOW and HIGH respectively.

IC11a input is a negative-going 22μsec pulse when drift correct commences. This is inverted and applied to NAND gates IC10a and b. Both IC10b inputs are now HIGH and that gate opens applying a 22μsec negative-going pulse to inverter IC10c. The resultant positive pulse charges C9 and C10 via MR3. Because the values of the two capacitors are in the ratio 1 000:1, the +5 volt pulse from IC10c charges C10 to +5mV which is sufficient to increase the clock frequency by some 0.01%. If ramp up still ends after point X, a similar process will take place during the following drift correct periods until synchronisation with the mains is achieved.

When ramp up ends before point X, consideration of figure 3.15 shows that, although the clock frequency adjust bistable is again toggled by the negative-going edge of the 25Hz waveform, a HIGH steering input is now derived from IC7 pin 6 and applied to IC9 pin 4. IC9 pin 9 is now set to LOW but IC10a inputs are both HIGH at the beginning of drift correct. IC10a output is a negative 22μsec. pulse which charges C10 to -5mV via MR2 to decrease the clock frequency and hence lengthen the ramp up period.

The network MR4, MR5 and MR6 in conjunction with the base/emitter diodes of VT3 and VT4, ensures that MR2 and MR3 are reverse biased when pulses are not being applied to C8 and C9.

By making each frequency adjustment relatively small, sudden spurious variations in mains frequency will be effectively ignored by the logic. The more usual slow variations in the 50Hz supply will, however, be accurately followed.

Polarity and Reset Pulses

After completion of ramp up and again at the end of ramp down, the counters must be reset to zero. The result of the polarity decision previously taken must also be passed to the display.

Suppose that the polarity is such that the potential on pin 6 of IC1b [part of the polarity bistable] is HIGH. Pins 2 and 5 of IC13a and b respectively will be at this same potential. Figure 3.16 shows the conditions obtaining at IC13b inputs and the consequent output on pin 6 which is also one input of NAND gate IC13c.

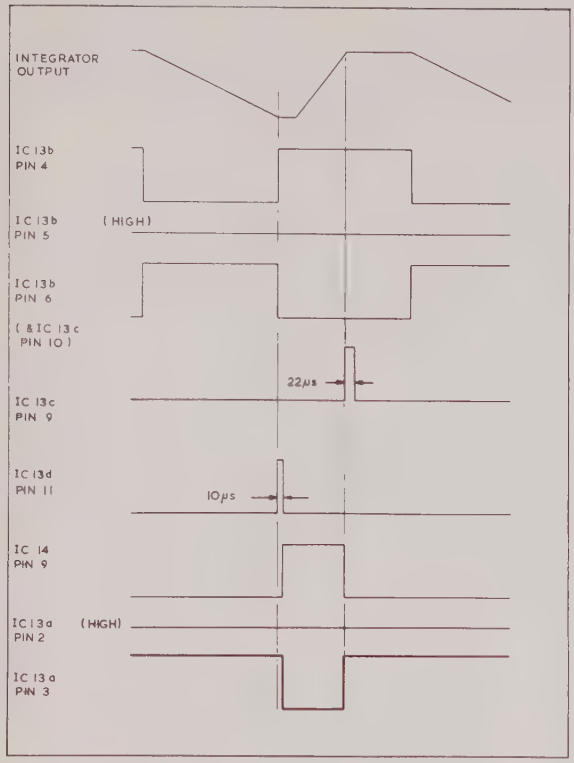


Figure 3.16 Polarity and Reset Pulse - Negative Polarity

IC13c second input is derived from the drift correct pulse. When, at the beginning of drift correct, IC10d pin 11 changes from a HIGH to a LOW, a 22μsec. negative-going pulse on IC11a pin 1 is inverted and applied to the second input of IC13c. Comparison of the waveforms on pins 9 and 10 of IC13c shows that at no time do two HIGH inputs coincide. IC13c therefore remains closed for the complete measurement cycle.

The 10μsec. positive-going pulse at the output of IC13d at the termination of ramp up toggles IC14 on its trailing edge setting pin 9 to a HIGH. IC14 is reset by the leading edge of the negative-going drift correct pulse from IC10d. Comparison of this, the second input to NAND gate IC13a, and the steady HIGH on IC13a pin 2 gives the output on pin 3, shown in figure 3.16. Since the outputs of IC13a and c are wired together, they effectively form an OR gate giving a LOW on edge connector pin 5 when either gate output is LOW. Hence IC13a output also appears at the edge connector.

Suppose now that the polarity decision had been such that a LOW were applied to pins 2 and 5 of NAND gates IC13a and b. The outputs from both gates, being inhibited, will stay HIGH. IC13c therefore opens and passes inverted 22μsec. pulses from IC11a to edge connector pin 5 as shown in figure 3.17.

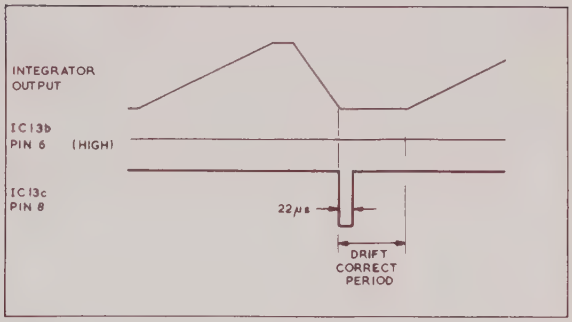
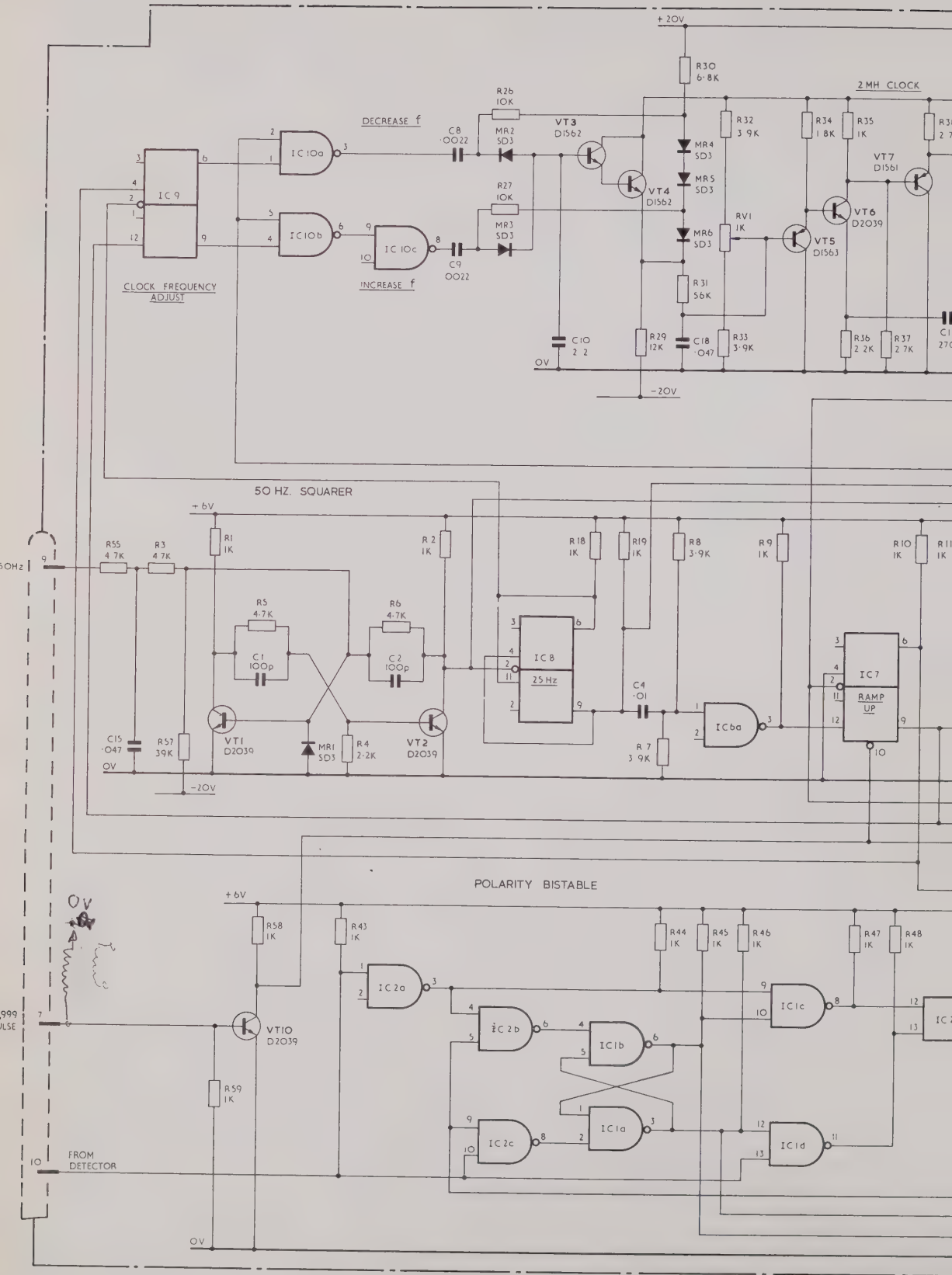


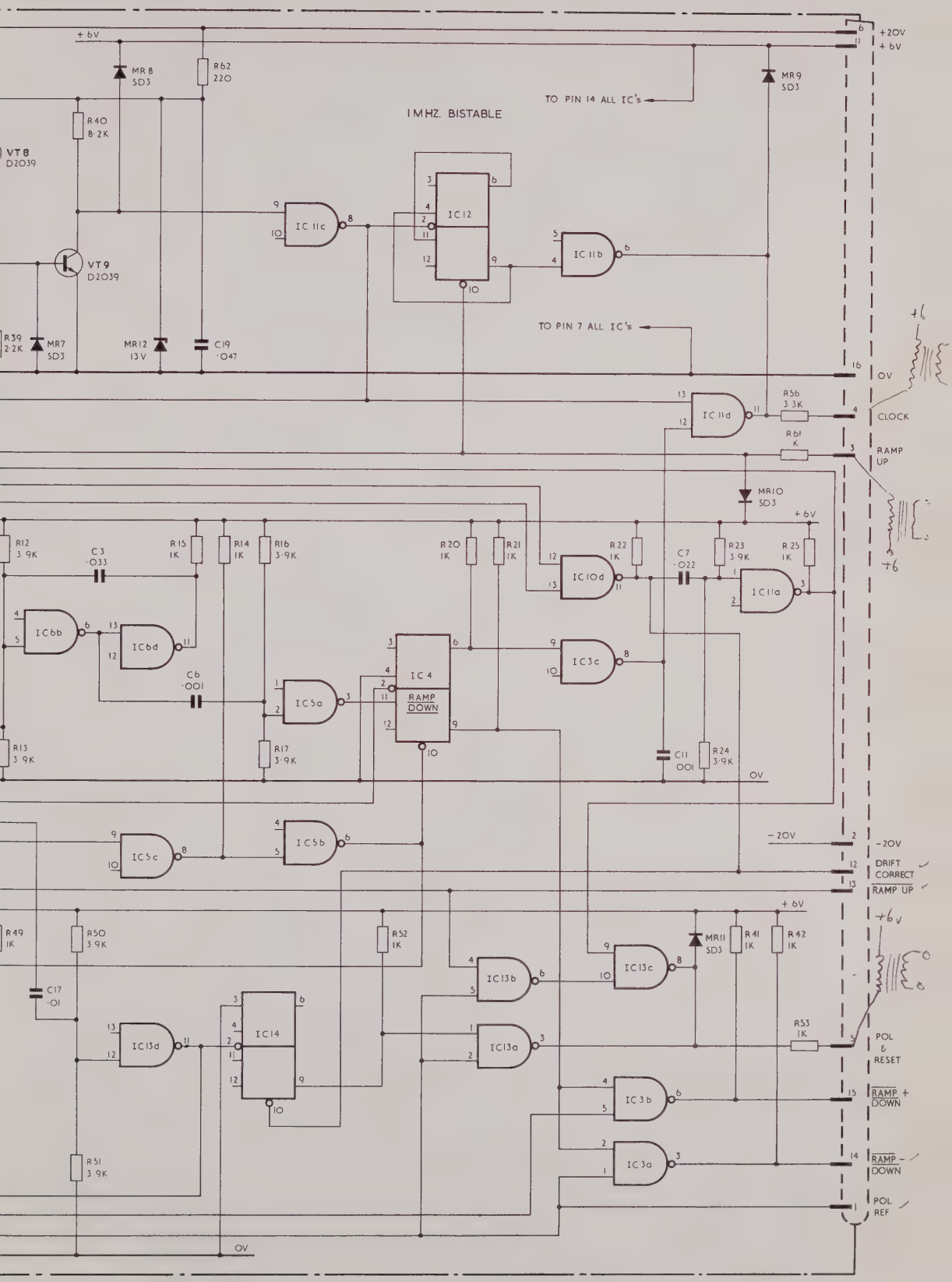
Figure 3.17 Polarity and Reset Pulse - Positive Polarity

The waveform on edge connector pin 5 is thus a negative-going pulse, the timing of which varies with the polarity of the input. A pulse transformer couples these pulses to the earthy logic circuitry which deduces the polarity of the voltmeter input by examining the timing of their leading edges.

The positive-going trailing edges of the same pulses are used to reset the counter to zero after ramp down has been completed.

On switching on the instrument, a condition could occur in which the counters were 'locked out' i.e. fixed at some nominal count. No 19999 pulse would be received and ramp up would not be terminated. In this case, NAND gate IC13b will be held closed by the LOW from IC7 and will maintain a HIGH on IC13c pin 10. A reset pulse will be generated when the next 22μsec. pulse arrives from IC11a resetting all counters and allowing normal operation to begin.


+20V
R30 6·8K
2 MH CLOCK
DECREASE f
R26 10K
C8 ·0022
MR2 SD3
VT3 D1562
R32 3·9K
R34 1·8K
R35 1K
VT7 D1561
IC 10a
IC 9
IC 10b
IC 10c
R27 10K
MR3 SD3
MR4 SD3
MR5 SD3
VT4 D1562
VT6 D2039
VT5 D1563
RV1 1K
MR6 SD3
C9 0022
INCREASE f
CLOCK FREQUENCY ADJUST
R31 56K
C10 2·2
R29 12K
C18 ·047
R33 3·9K
R36 2·2K
R37 2·7K
0V
-20V
50 HZ. SQUARER
+6V
R55 4·7K
R3 4·7K
R1 1K
R2 1K
R18 1K
R19 1K
R8 3·9K
R9 1K
R10 1K
R5 4·7K
R6 4·7K
C1 100p
C2 100p
IC 8
25 Hz
IC7
RAMP UP
C4 ·01
IC6a
C15 ·047
R57 39K
VT1 D2039
MR1 SD3
R4 2·2K
VT2 D2039
R7 3·9K
POLARITY BISTABLE
R58 1K
R43 1K
R44 1K
R45 1K
R46 1K
R47 1K
R48 1K
IC 2a
IC 2b
IC 2c
IC1b
IC1a
IC1c
IC1d
VT10 D2039
R59 1K
FROM DETECTOR



02 3.8.68

Floating Logic

Board No. 1

D 1604930 1

Slave Ramp Up Bistable

The positive-going ramp up pulse from edge connector pin 3 on board 1 is coupled via a pulse transformer to edge connector pin 23 on board 2 - being differentiated in the process. The positive-going edge is inverted by VT5 and triggers one input of the slave ramp up bistable. The negative-going edge is applied via VT7, VT6 and IC3d to the second input of the bistable which therefore operates in parallel with the master ramp up bistable on board 1 as illustrated in figure 3.18.

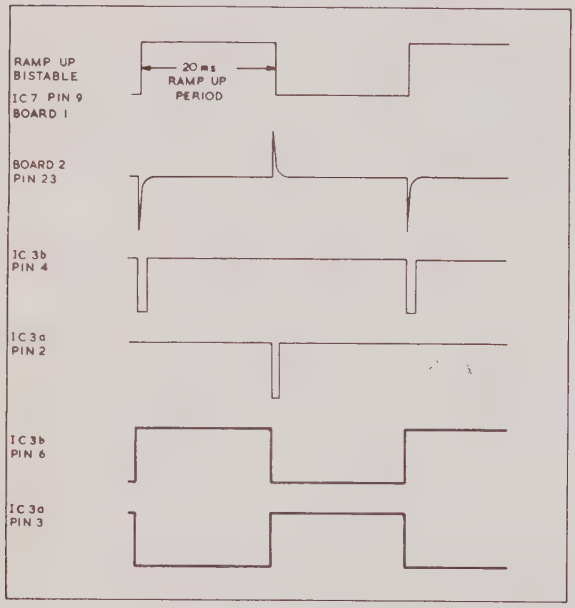


Figure 3.18 Slave Ramp Up Bistable Operation

An output is taken from pin 3 of IC3a providing an output pulse which is LOW during ramp up.

Display Polarity Decisions

General

Polarity bistable IC2a and b is triggered by the output from NAND gate IC2d and by the negative-going pulse from VT5 collector corresponding to the end of the ramp up period. The output from IC2d depends both on the state of the slave ramp up bistable and the timing of the polarity pulse from board 1.

Positive Polarity

Figure 3.19 shows IC2d inputs and outputs for a positive polarity input to the voltmeter.

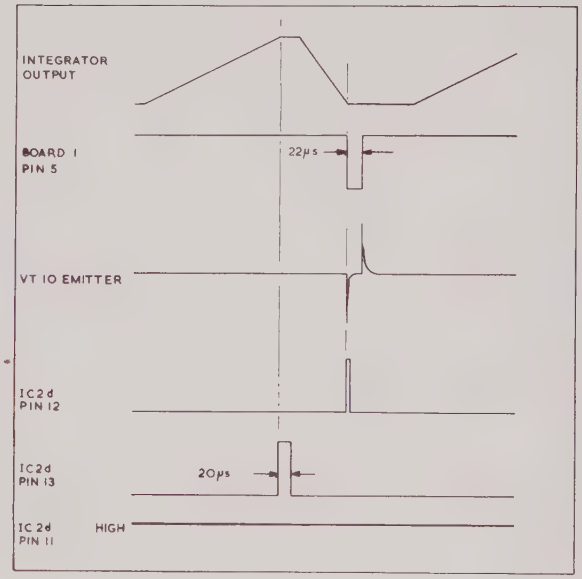


Figure 3.19 IC2d Operation - Positive Polarity

At the end of ramp up, IC3b pin 6 falls from a HIGH to a LOW. The differentiating circuit C1, R15 and R17 applies a negative-going pulse of 20μsec. duration to IC2c pin 9 which, after inversion, forms one input to IC2d.

As explained in the section 'Polarity and Reset Pulses', the output from the floating logic board 1, for a positive voltmeter input, is the 20μsec. negative-going pulse of figure 3.17. This is differentiated by the pulse transformer whose secondary connects to edge connector pin 24 and the leading negative edges are inverted by VT9 to supply the second input to IC2d. A consideration of the two inputs to IC2d shows that since, at no time are both signals HIGH, the output is a permanent HIGH.

When a positive-going staticising pulse is applied to NAND gates IC1c and d during the drift correct period, the polarity bistable output is transferred into the polarity store bistable IC1a and b. In this case, the HIGH on IC2b pin 6 opens IC1c and the LOW transferred to IC1b pin 4 sets the bistable such that pin 6 is HIGH and pin 3 LOW. VT1 is switched on by the output from IC1b and the positive sign neon indicator in the display strikes.

Figure 3.20 shows the inputs to the polarity bistable and the consequent outputs.

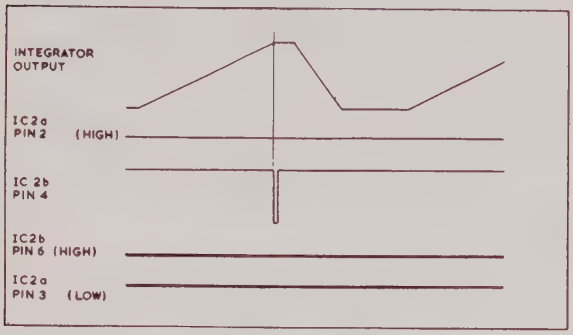


Figure 3.20 Polarity Bistable Operation - Positive Polarity

Negative Polarity

Figure 3.21 shows IC2d inputs and output when a negative polarity voltage has been connected to the voltmeter input terminals.

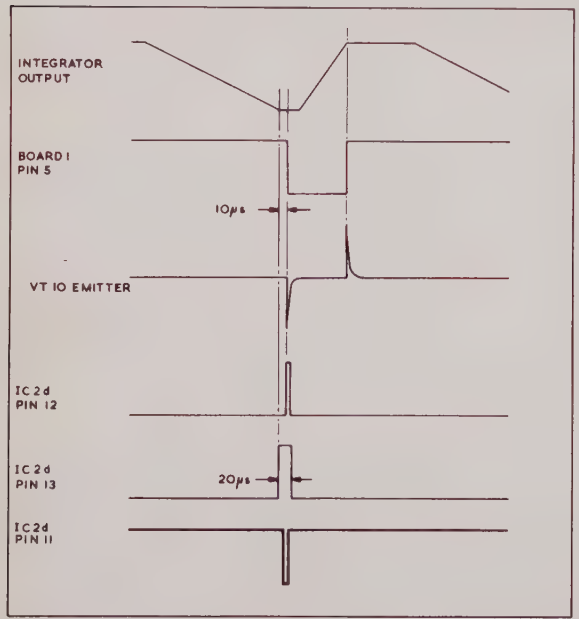


Figure 3.21 IC2d Operation - Negative Polarity

There is now a coincidence between the HIGH signals present at IC2d inputs causing the pulse on pin 11 of approximately 2μsec. duration. The inputs to the polarity bistable are now as shown in figure 3.22.

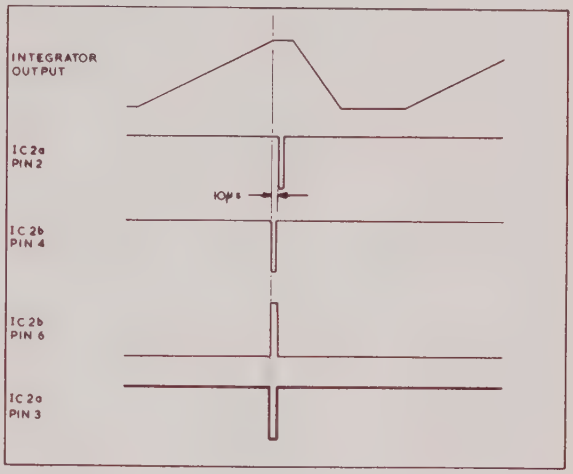


Figure 3.22 Polarity Bistable Operation - Negative Polarity

Staticisation still occurs at the same point during the drift correct period but in this case as the polarity bistable has been turned over by the previous pulse from IC2d, the information transferred to the polarity store sets IC1b pin 6 to a LOW. The HIGH present on IC1a pin 3 switches on VT2 and the negative sign neon indicator in the display strikes.

An output taken from IC2a pin 3 is passed via edge connector pin 6 to the fan out unit [if fitted] and the positive-going edge generated after ramp up indicates a negative polarity input to the instrument.

The output at IC1b pin 6 is also fed to the fan out unit but a positive-going edge will now signify a positive polarity input and will not occur until the staticise pulse has written the polarity bistable decision into the polarity store [i.e. during drift correct].

AC Operation

When used for the measurement of a.c., the junction of diodes MR1 and MR2 is returned to 0 volts. The outputs from the polarity store are therefore clamped at this potential and transistors VT1 and VT2 are permanently switched off so that neither the positive nor the negative neon can be struck.

Display Counter Reset Pulses

Assuming a negative polarity input to the voltmeter then the output from the polarity and reset logic circuitry on board 1 is as shown in figure 3.23.

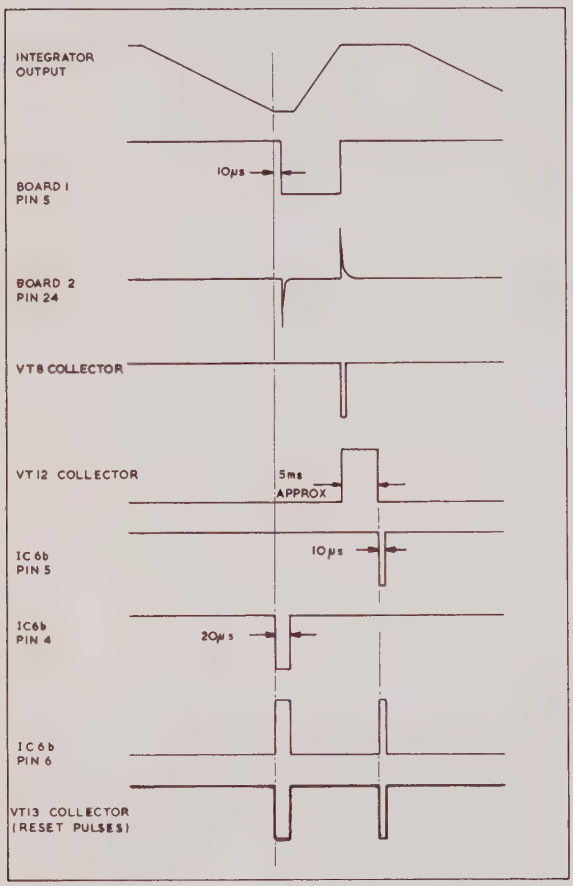


Figure 3.23 Reset Pulses - Negative Polarity Input

After differentiation by the pulse transformer, the negative pulse at VT8 collector is used to start the delay monostable VT11, VT12. VT12 collector waveform is a positive-going pulse of some 5msec. duration and is differentiated before being applied to IC6b pin 5. The input to pin 4 of IC6b is a differentiated pulse derived from the negative-going slave ramp up edge on IC3b pin 6 and is shown in figure 3.23. Both inputs to IC6b are normally held HIGH by potential dividers. The incidence of a negative edge at either input will thus cause the output to change from LOW to HIGH and apply a positive-going input to VT13 base switching that transistor on. From figure 3.23 it can be seen that two such positive pulses are generated during each measurement cycle - one at the end of ramp up and a second during drift correct. These are inverted by VT13 and the negative-going edges used to return all the display counters to zero.

When a positive polarity voltage is being measured, the waveform on edge connector pin 24 alters to that shown in figure 3.24 [refer to section 'Floating Logic-Polarity and Reset Pulses'].

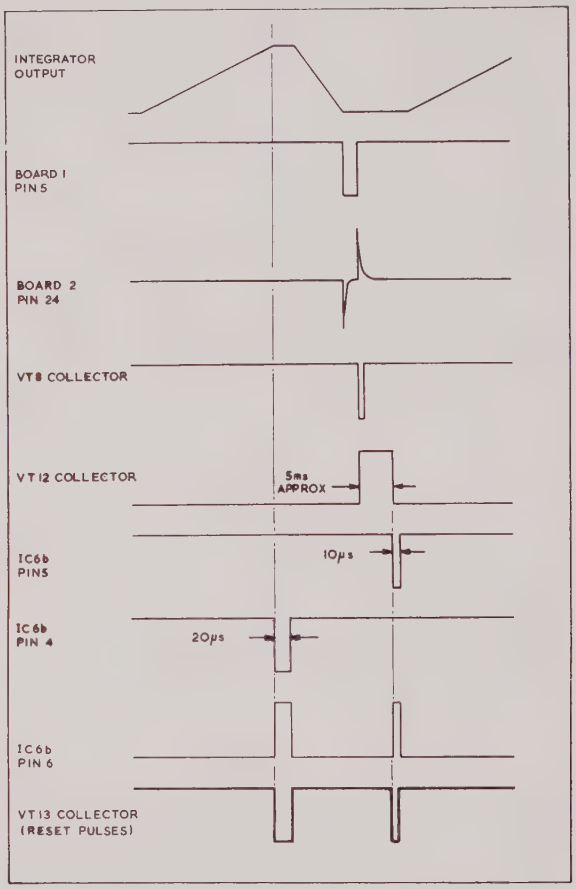


Figure 3.24 Reset Pulses - Positive Polarity Input

The input on pin 5 of IC6b is consequently modified slightly but, as before, one reset pulse is generated at the end of ramp up while a second occurs during drift correct.

Staticising

General

The counters accumulate pulses both during ramp up and ramp down. Also, the state of the polarity bistable may change during the measurement cycle. If connected directly to the display neons, this rapidly changing information would give rise to a flickering and probably confusing read-out. Staticisation, by ensuring that the contents of the counters and store are only transferred to the neons when steady, provides a clearly readable and static display.

25/s Mode

Staticising varies with the mode of operation of the voltmeter. When sampling at 25/sec. a staticise pulse is generated once for every measurement cycle. A permanent LOW is connected to pin 10 of the hold bistable IC4c and d by the 25/sec. push button SB1. IC4c pin 8 is consequently held at a permanent HIGH which is applied to IC3c. The positive-going pulse on VT6 collector at the commencement of ramp up provides a second HIGH input to IC3c which opens and applies a LOW to pin 4 of the read bistable IC4a and b. The read bistable is now set such that pin 6 is HIGH.

When the reset pulse fires the delay monostable, the positive edge at VT12 collector opens IC6a whose LOW output switches off VT4 via the differentiator C8, R43. A positive-going staticise pulse is generated at VT4 collector of approximately 40μsec. duration as shown in figure 3.25.

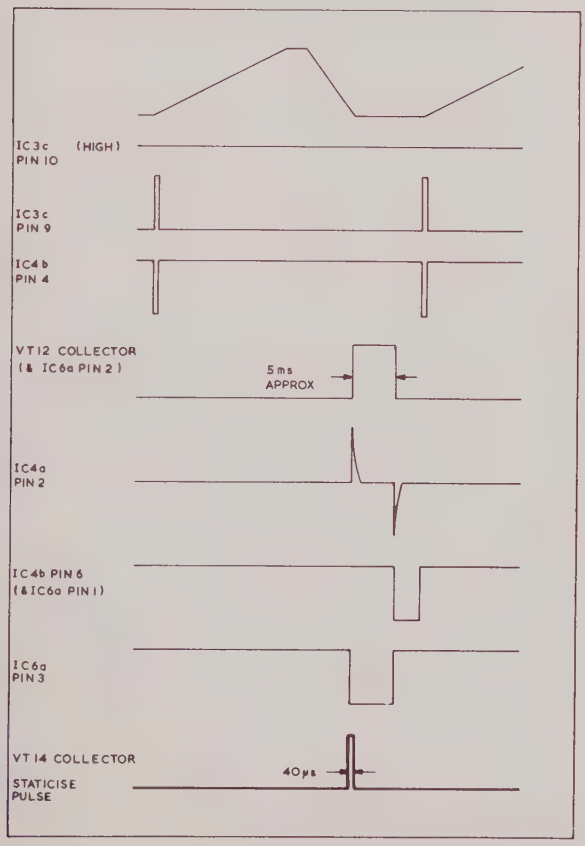


Figure 3.25 Staticise Pulses

When VT12 collector reverts back to a LOW at the end of the delay period, the negative-going 10μsec. pulse applied by the differentiating circuit C7, R3 and R39 to IC4a pin 2 resets the read bistable to inhibit NAND gate IC6a. This cycle is repeated every 40msec., [i.e. 25/sec.] with the contents of the counter and polarity store being held displayed for the whole of this period.

Manual Sample Mode

In the manual sample mode, staticise pulses are only generated when the voltmeter receives a command to sample [either from the push button on the front panel or externally via the fan out unit].

The 25/sec. push button SB1 is now open circuited and the clamping voltage removed from the hold bistable. Depression of SB2 connects edge connector pin 10 to 0 volts applying a negative-going 25μsec. pulse to pin 9 of IC4c. The hold bistable is thus set with a HIGH on IC4c pin 8 and a LOW on IC4d pin 11.

At the beginning of the next ramp up period, the sequence described in the preceding section ensues and a staticise pulse is produced as before. However, when the read bistable is reset at the end of the delay period, the HIGH on IC4a pin 3 opens IC6c whose LOW output resets the hold bistable. No further staticise pulses can be generated until the hold bistable is again set by pressing the MANUAL sample push button SB2. [When no auto-range board is fitted, IC6c behaves merely as an inverter. When the voltmeter has an auto-range board, the inhibit hold line is held HIGH providing that auto operation is not selected.]

Remote Sample

When neither the 25/s nor the MANUAL SAMPLE buttons are pressed, manual sampling may be commanded by - for example - an external relay contact earthing SKB pin 19. The logic sequence is identical to that described in the section 'Manual Sample Mode' except that operation of push button SB2 is simulated by the external source.

Print Command Signals

When used with external equipment e.g. a print-out device, a print command signal is available for initiating a print out. In the 25/sec. mode of operation the print command line is permanently held LOW and therefore inoperative. When manual or auto-range operation is selected however, a HIGH print command signal is produced at edge connector pin 16 when the measurement of the input voltage has been completed at the end of the 5msec. delay period provided by VT11 and VT12.

Manual Sample

IC4d pin 11 changes to a LOW when a sample is commanded by the application of a LOW to edge connector pin 10. As described in the section 'Staticising - Manual Sample Mode', IC4d pin 11 reverts to a HIGH at the end of the 5msec. delay period. Figure 3.26 shows the print command pulse generated in this mode.

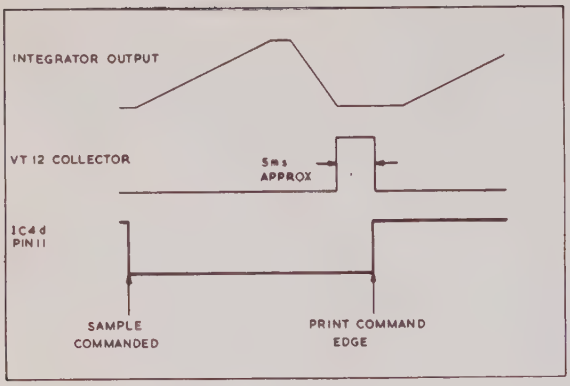


Figure 3.26 Print Command - Manual Sample Mode

On auto operation, the voltmeter examines the input voltage and automatically selects the appropriate range. It may be necessary to look at the input over several measurement cycles before a final range decision is reached. To prevent the inaccurate readings, which may occur during the range decision period, from being recorded, an inhibiting LOW is maintained on edge connector pin 8 by the auto range board until the correct range has been selected. Thus when AUTO and MANUAL buttons are depressed, IC6c is inhibited and the hold bistable can not be reset from the read bistable. No print command pulse will be generated neither will it be possible to command the hold bistable by applying a LOW to edge connector pin 10. When the range decision has been made and IC6c pin 9 is returned to a HIGH, the next positive-going edge to occur at IC4a pin 3, generates a LOW on pin 8 of IC6c resetting the hold bistable at the end of the 5msec. delay period as before. A print command signal now occurs on IC4d pin 11 and a LOW applied to edge connector pin 10 will command a further sample.

10000 Indication

On reaching a count of 10000, the counter issues a negative-going pulse which toggles IC7 via edge connector pin 20 and sets pins 6 and 9 to LOW and HIGH respectively. When the staticise pulse is applied to NAND gates IC5c and d, the former opens applying a LOW to pin 4 of IC5b. IC5b pin 6 is thus set to a HIGH and, by bistable action, IC5a pin 3 is set to a LOW. VT3 is switched off by the resulting negative voltage on its base allowing the collector to rise towards +250 volts and the 10000 neon to strike. The next reset pulse causes IC7 to revert to the other state and, if no 10000 pulse is received from the counter, VT3 will conduct to short out the neon indicator when the next staticise pulse resets bistable IC5a and b.

19999 Pulse and Overload Indication

During ramp up, when a count of 9999 is registered by the counters, an inhibiting LOW is removed from edge connector pin 4. At a count of 19999, bistable IC7 is set as before and MR11 reverse biased. VT15 base is therefore allowed to rise positively and that transistor switches on generating a LOW on its collector. This edge is coupled via a pulse transformer into the floating logic board 1 and resets the ramp up bistable.

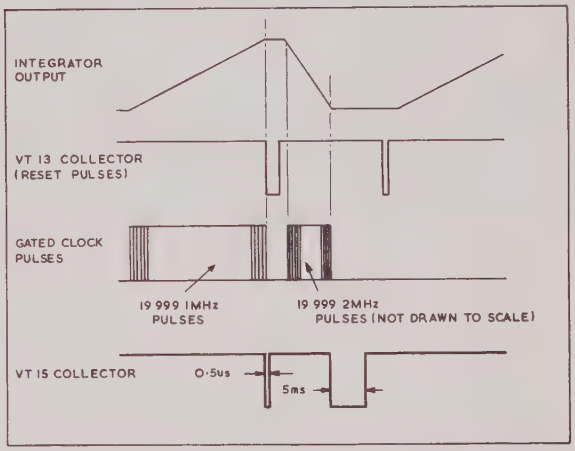


Figure 3.27 19999 Pulse and Overload Indication

From figure 3.27 since the counters are immediately reset to zero, the duration of the 19999 pulse is short - approximately 0.5μsec. Although VT4 is switched off by this pulse and the overload neon is connected to +250 volts via R8, no overload indication will be observed since the neon does not have time to strike.

If the counters should reach 19999 during the ramp down period - signifying that an excessively large input has been applied to the voltmeter - VT15 is again switched on. The counters will not now be reset until the 5msec. delay period has elapsed - this being long enough to provide a visible flashing overload indication.

DISPLAY AND COUNTERS

General

The counter comprises four identical printed circuit boards. Each board contains a divide by ten counter, a staticised binary store, a binary to decimal decode network and a neon indicator tube with its associated drive circuit. The counters are connected in cascade to give a full house capability of 9999. The ten thousandth input pulse resets the counters to zero but causes a 10000 carry signal to be passed to bistable IC7 on board 2 striking the 10000 neon indicator, [refer to section '10000 Indication']. A further 9999 pulses can be accumulated in the counters before the reset pulse is generated at 19999 and they are returned to zero.

When the staticise pulse occurs, the number held in the individual counters is transferred to the stores and decoded into the decimal drive required for the neon indicators. Since the staticise pulse [derived from the earthy logic board and described in the section 'Staticising'] arrives during the drift correct period, the number displayed is the quantity of 2MHz pulses accumulated during ramp down.

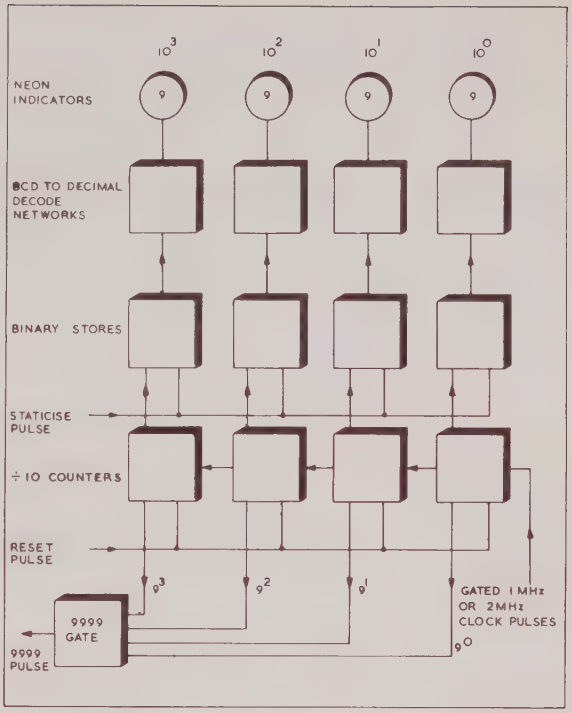


Figure 3.28 Display and Counters - Block Diagram

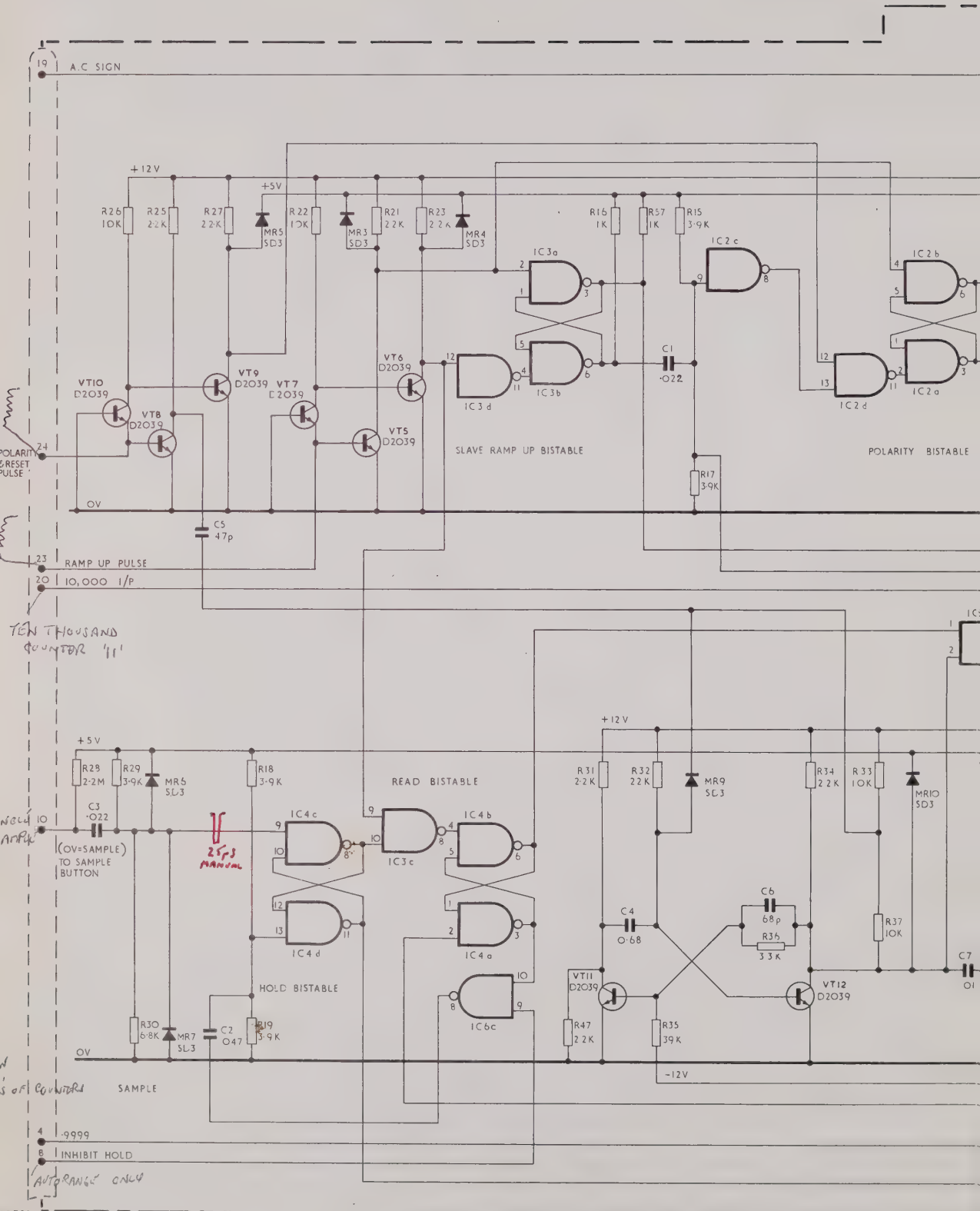
Binary Counter

IC5-IC8 constitute a four bit binary counter whose full house capability has been reduced to nine by appropriate interconnection of inputs and outputs. 1MHz or 2MHz gated clock pulses from the floating logic board 1 are applied to the first counter stage via a pulse transformer and amplifier VT1 on board 8.

INPUT TO IC5 PIN 2 [NO. OF PULSES]	IC5 PIN 6	IC6 PIN 6	IC7 PIN 6	IC8 PIN 6
0	LOW	LOW	LOW	LOW
1	HIGH	LOW	LOW	LOW
2	LOW	HIGH	LOW	LOW
3	HIGH	HIGH	LOW	LOW
4	LOW	LOW	HIGH	LOW
5	HIGH	LOW	HIGH	LOW
6	LOW	HIGH	HIGH	LOW
7	HIGH	HIGH	HIGH	LOW
8	LOW	LOW	LOW	HIGH
9	HIGH	LOW	LOW	HIGH
10	LOW	LOW	LOW	LOW

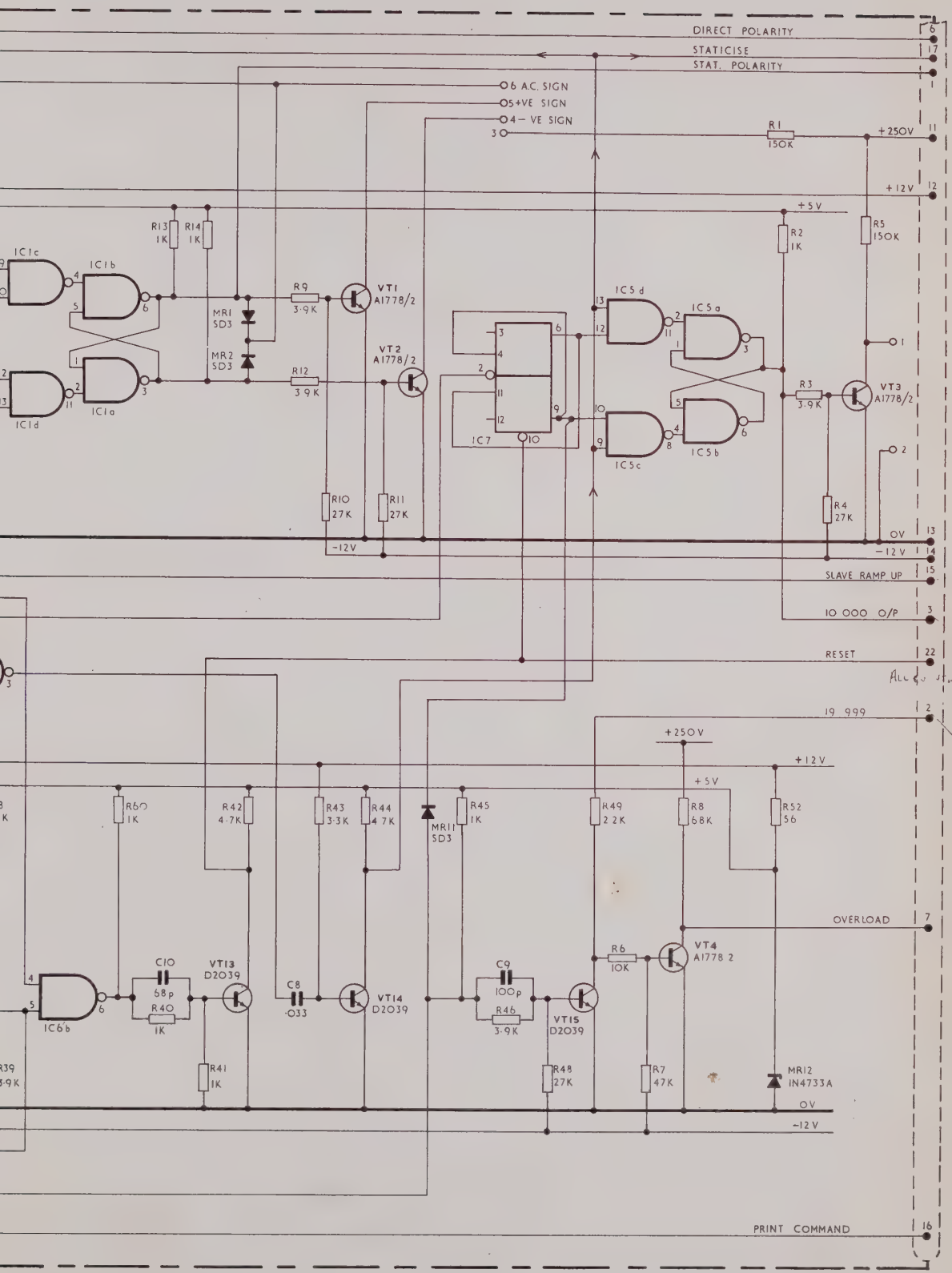
[The output from pins 9 of the bistables is naturally the complement of pins 6.]

Table 3.2 Binary Counter Truth Table



D 2039 = 2N2369 on this board.

02 8·9·69



Earthy Logic

Board No. 2

D 16109302

Table 3.2 shows the state of pin 6 of each bistable in the counter. Note that the tenth pulse to arrive at edge connector pin 12 resets IC5 and IC8 but that the input gates are so connected as to prevent the negative-going edge produced at IC5 pin 6 from triggering IC6.

The negative-going reset pulses from the earthy logic board 2 are applied in parallel to all counter bistables setting pins 6 to LOW. The counter output [input divided by 10] is taken via edge connector pin 11 to the succeeding counter.

Staticised Store

Pins 8 and 9 of each counter bistable are connected to NAND gates which remain inhibited until the arrival of a staticise pulse from the logic on board 2.

Considering just one of the counter bistables, suppose IC5 is in the operated state i.e. has stored one input pulse from the clock. Although IC1a is inhibited by the LOW from IC5 pin 6, IC1d will open when the staticise pulse provides its second HIGH input. Store bistable IC1b and c will consequently be set such that pin 6 is a LOW and pin 8 HIGH. The bistable remains set in this state until the incidence of the next staticise pulse 40msec. later when the condition of IC5 will again be examined and stored.

Binary to Decimal Decode

Ten transistors arranged in pairs determine which of the ten numerals available in each neon indicator shall be illuminated, each pair controlling one odd and one even numeral. Decoding is achieved firstly by determining whether the required numeral is odd or even and selecting the appropriate transistor in each pair, and secondly by selecting the required pair according to information held in the store.

If, for explanation purposes, we assume that seven clock pulses have passed into the binary counter when staticisation occurs then, from table 3.3, the potentials on the cathodes of MR2 and MR4 are +5 volts and 0 volts respectively. Similarly it can be seen that +5 volts is present on the cathodes of MR13 and 14. These diodes conduct and apply +5 volts to the bases of VT7 and VT8. From table 3.3 it will be seen also that at least one of the diodes connected to the bases of all other transistors has a LOW on its cathode. Thus all transistors, except for the two already mentioned, are held cut off by the 0 volts on their bases.

Since VT8 emitter is returned to 0 volts via MR4, that transistor conducts and the numeral 7 will be lit in the neon indicator. Once conducting, VT8 base remains at approximately +0.5 volt eliminating any possibility of VT7 being switched on. Should the number held in the store change to, say, 6 then the +5 volts applied via MR4 switches off VT8. VT7 will now conduct, however, since its emitter is returned to 0 volts via MR2.

No. in store	Store outputs LOW	Store outputs HIGH	Gate opened	Transistor selected	No. displayed
0	1 2 4 8	$\overline{1}$ $\overline{2}$ $\overline{4}$ $\overline{8}$	MR5, 6, 7	VT1	0
1	$\overline{1}$ 2 4 8	1 $\overline{2}$ $\overline{4}$ $\overline{8}$		VT2	1
2	1 $\overline{2}$ 4 8	$\overline{1}$ 2 $\overline{4}$ $\overline{8}$	MR9, 10	VT3	2
3	$\overline{1}$ $\overline{2}$ 4 8	1 2 $\overline{4}$ $\overline{8}$		VT4	3
4	1 2 $\overline{4}$ 8	$\overline{1}$ $\overline{2}$ 4 $\overline{8}$	MR11, 12	VT5	4
5	$\overline{1}$ 2 $\overline{4}$ 8	1 $\overline{2}$ 4 $\overline{8}$		VT6	5
6	1 $\overline{2}$ $\overline{4}$ 8	$\overline{1}$ 2 4 $\overline{8}$	MR13, 14	VT7	6
7	$\overline{1}$ $\overline{2}$ $\overline{4}$ 8	1 2 4 $\overline{8}$		VT8	7
8	1 2 4 8	1 2 4 8	MR15	VT9	8
9	$\overline{1}$ 2 4 $\overline{8}$	1 $\overline{2}$ $\overline{4}$ 8		VT10	9

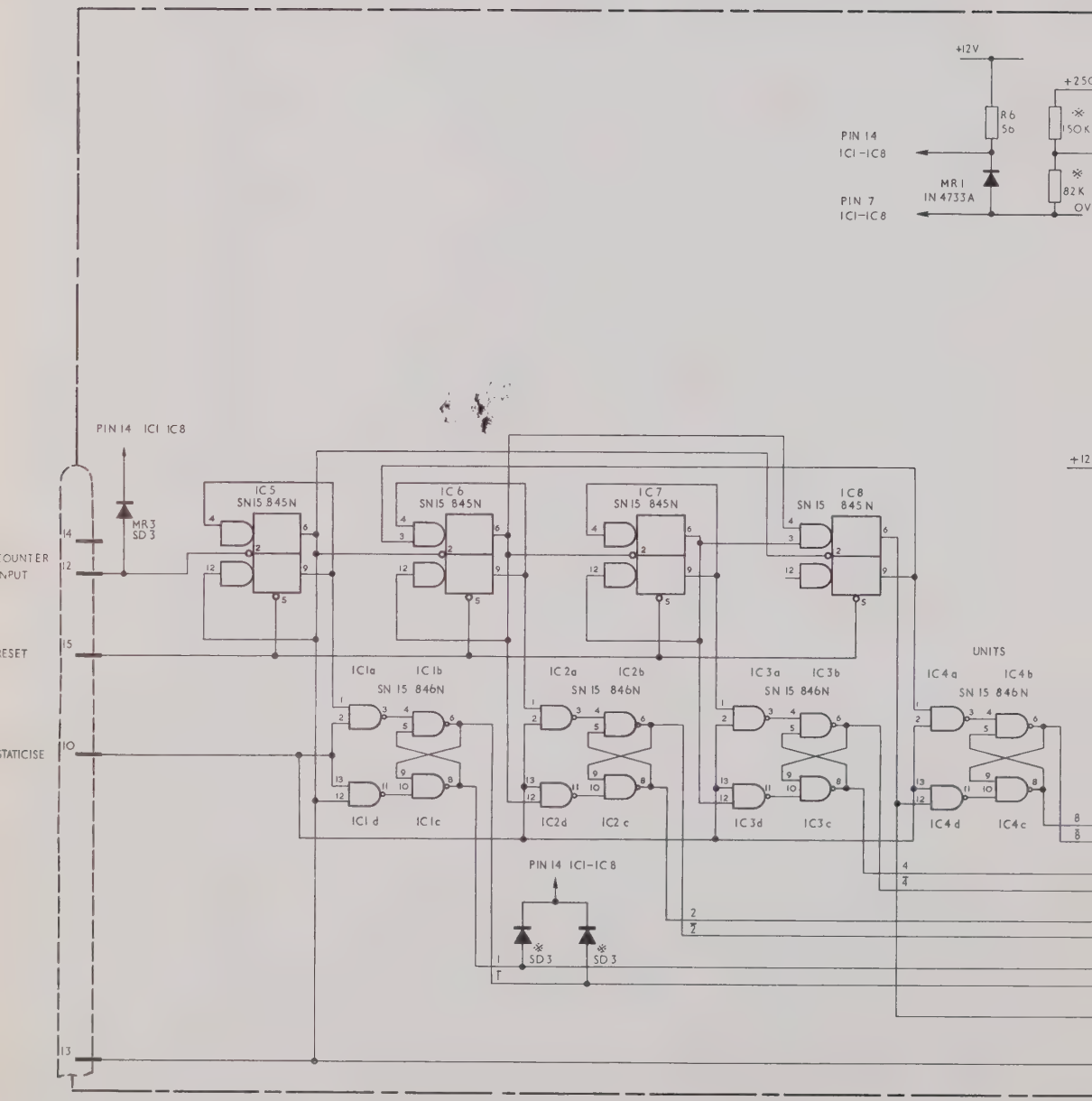
Table 3.3 Binary to Decimal Decode

9999 Gate

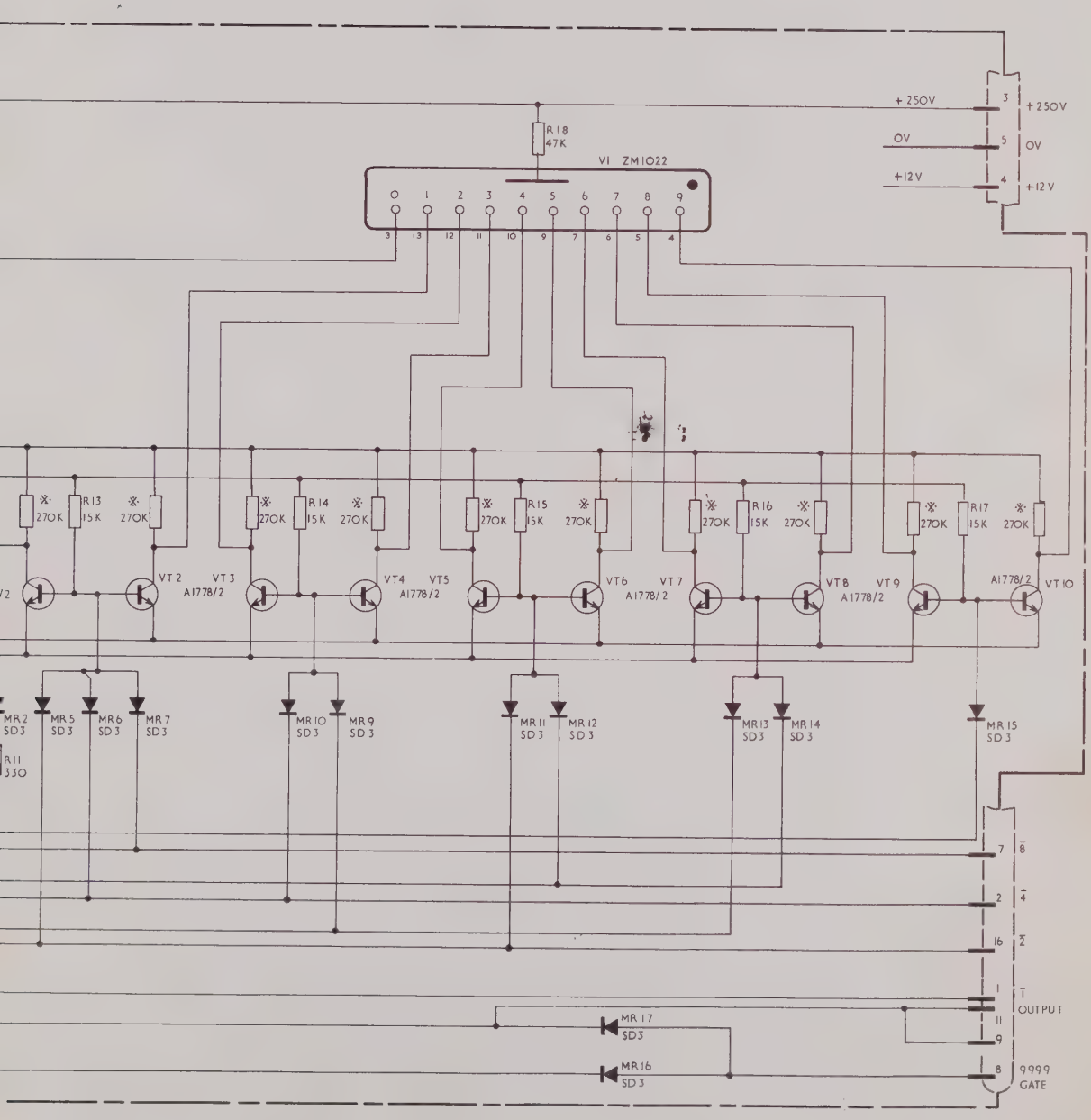
MR16 and 17 on all four counter boards in conjunction with MR11 and R45 on the earthy logic board form an AND gate whose output is HIGH when all inputs are HIGH. This only occurs when each counter has accumulated nine clock pulses and the 10000 bistable on board 2 has been set i.e. 19999 clock pulses have been received.

Staticised Outputs

A staticised binary output is fed via edge connector pins 1, 2, 7 and 17 to the fan out socket for external use if required. The presence of a LOW at these pins signifies that the particular digit has been stored and passed to the display.



NOTE
ALL COMPONENTS MARKED THUS ※
ARE NOT FITTED, BUT THE P.C.B
COPPER IS DESIGNED TO ACCOMODATE
THEM, IF REQUIRED



Display Counter

Board No. 20

16109320

Table 3.4 Socket SKB Pin Connections

Pin No.	Function	Remarks
1	$\overline{1}$	Staticised B.C.D. outputs presented in parallel with the displayed reading - a HIGH indicating the bits not displayed.
2	$\overline{2}$	
3	$\overline{4}$	
4	$\overline{8}$ Units [10_0]	
5	$\overline{1}$	
6	$\overline{2}$	
7	$\overline{4}$	
8	$\overline{8}$ Tens [10_1]	
9	$\overline{1}$	Refer to 'Display and Counters' and Table 3.3.
10	$\overline{2}$	
11	$\overline{4}$	
12	$\overline{8}$ Hundreds [10_2]	
13	$\overline{1}$	
14	$\overline{2}$	
15	$\overline{4}$	
16	$\overline{8}$ Thousands [10_3]	
17	$\overline{1}$ Ten thousand [1_4]	
18	Polarity	Staticised polarity information. A HIGH signifies positive polarity. Refer to 'Earthy Logic - Display Polarity Decisions'.
19	Sample	Staticisation is commanded by applying a LOW when the 25/s push-button is not depressed. Refer to 'Earthy Logic - Manual Sample'.
20	Print Command	A HIGH indicates that a measurement has been completed. Refer to 'Earthy Logic - Command Signals'.
21	10mV	A LOW indicates the range in use or - on remote operation - ranges are commanded by applying 0 volts to these pins. Refer to section 'Range Switching and Mode Selection'.
22	100mV	
23	1V	
24	10V	
25	100V	
26	1000V Decimal Range Commands	
27	Remote AC	A LOW indicates that the voltmeter is programmed to measure a.c. or, if the Remote push-button is depressed, a.c. range relays are energised by the application of a LOW. Refer to 'Range Switching and Mode Selection - A.C. Mode'.
28	$\overline{\text{Ramp Up}}$	A LOW is produced during the ramp up period. Refer to 'Earthy Logic - Slave Ramp Up Bistable'.
29	Polarity	A HIGH signifies a negative polarity input. This is not a staticised output. Refer to 'Earthy Logic - Negative Polarity'.
30	Mains Earth	

Table 3.4 Socket SKB Pin Connections (cont.)

Pin No.	Function	Remarks
31 32	+12V] -12V]	Referred to mains earth.
33	Manual	A LOW signifies that the voltmeter is programmed for d.c. measurement. Refer to 'Range Switching and Mode Selection - D.C. Mode'.
34	Gated Clock	Counter input pulses. Refer to Figure 3.4.
35	Not used	
36	Auto Range	Auto Range operation [d.c. only] is commanded by applying a LOW. Refer to 'Auto Range Board EX3055'.

Logic Levels

HIGH	Output voltage	>+2.6V but <+6.5V
	Output current	<0.12mA
LOW	Output voltage	>0V but <+1.1V
	Sink current	<10mA

MEASUREMENT OF AC

Introduction

The basic d.c. voltmeter is extended to measure a.c. by inserting the EX 1605 a.c. conversion kit which consists of three printed circuit boards and a range relay assembly. No further adjustments are necessary.

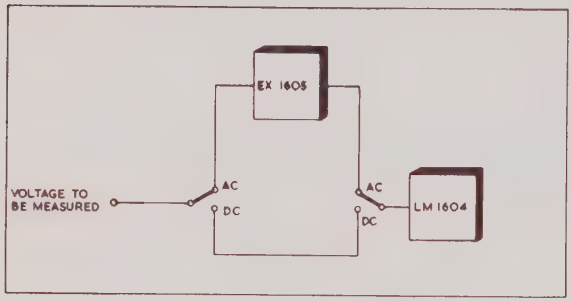


Figure 3.29 Measurement of A.C.

Principles of Operation

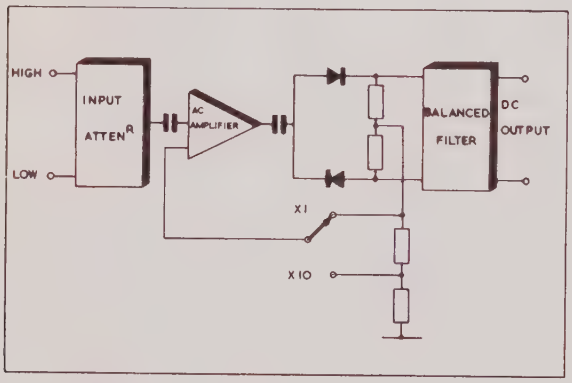


Figure 3.30 Basic Principle

The a.c. input is amplified and then rectified. The pulsating d.c. output from the rectifier is smoothed by one of three balanced filters, and then coupled to the d.c. input amplifier in the LM 1604 voltmeter. From this point, the signal is treated as a normal d.c. input with the display calibrated to indicate the RMS value of the a.c. present at the input terminals. The LM 1604 is automatically set to the IV range when the AC mode is selected.

A.c. gain of the amplifier is set to either X1 or X10 by suitably attenuating the reconstituted a.c. feedback voltage developed across the potentiometer chain while on the higher voltage ranges the input attenuator reduces the input signal to a level appropriate to the range in use.

Relay contacts operated either remotely or from the front panel range push-buttons define the amplifier operating conditions and attenuator settings.

Range Switching and Mode Selection

General

Plug PLA [free] pins 2-5 are supplied with +12 volts when a.c. ranges 100mV - 100V are selected by the bank of range push-buttons SH. If the 750V push-button is pressed none of these pins is energised.

DC Mode

Selection of the d.c. mode removes all inputs from PLA pins 2-5 and the a.c. drive from pin 8. Since no current flows through R4 or R14, transistors VT1 and VT4 both cut off whilst VT2 and VT3 conduct. Relays RLD and RLF are therefore energised and the a.c. unit, although isolated from the d.c. input amplifier, is set to the 750 volt range. On this range, the gain of the a.c. amplifier is a minimum with input attenuation a maximum, ensuring no interference to d.c. operation is caused by the a.c. unit.

AC Mode

When depressed the a.c. mode push-button SJ connects 0 volts to PLA pin 8 but removes the corresponding supply from the d.c. range relays. [Refer to section 'Range Switching and Mode Selection - A.C. Mode]. Hence, for a.c. operation, relays RLA and RLG are permanently energised.

100mV Range

The +12 volts connected by range switch SH3 to PLA pin 2 energises RLB and RLE. The voltages developed across R4 and R14 now switch on VT1 and VT4 which in turn, cut off VT2 and VT3 de-energising relays RLD and RLF. The a.c. input is thus connected directly to the amplifier whose gain is set to X10.

1V Range

The +12 volts applied to PLA pin 3 calls RLB but de-energises RLD. Since there is no current through R14, RLF is energised via VT3 as before. The a.c. input is again connected directly to the amplifier whose gain is now X1.

10V Range

The +12 volts on PLA pin 4 calls relays RLC and RLE but de-energises RLD and RLF. The a.c. input is connected via a ÷100 attenuator to the amplifier whose gain is set to X10.

100V Range

The +12 volts on PLA pin 5 energises RLC. Relay RLD is de-energised and RLF energised. The a.c. input is connected via the ÷100 attenuator to the amplifier whose gain is unity.

750V Range

Since none of the pins 2-5 on PLA are energised, relays RLD and RLF are called as when the d.c. mode has been selected. However, in this case, relays RLA and RLG are also energised. The a.c. input is connected via a ÷1000 attenuator to the amplifier whose gain is unity.

MODE	RANGE	RELAYS CALLED
D.C.	ALL RANGES	D F
A.C.	100mV	A B E G
	1V	A B F G
	10V	A C E G
	100V	A C F G
	750V	A D F G

Table 3.5 A.C. Ranging

All relays have the damping network previously described connected across the coils. [Refer to section 'Range Switching and Mode Selection - Relay Switching']

AC Amplifier Switching

Basically, the full-wave rectified output from the a.c. amplifier is re-constituted and applied to a dividing chain. A portion of this output is then fed back to the input to control the a.c. closed loop gain. The contacts of the relays detailed in table 3.5 select the required feed-back ratio and also, on the higher voltage ranges, switch in an input attenuator.

1V Range

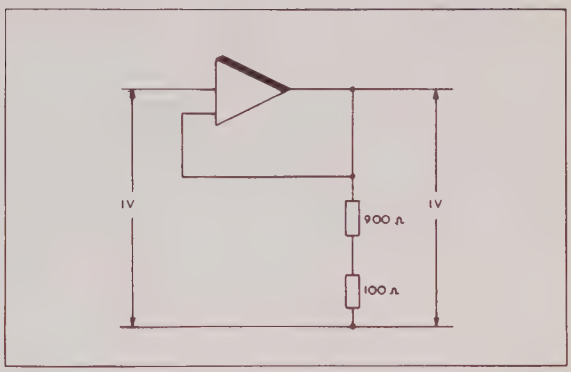


Figure 3.31 A.C. Amplifier - 1V Range

On this, the basic a.c. range, relay contact RLB/1 connects the voltage to be measured directly to the amplifier input. Relay contact RLF/1 selects the position on the output divider chain approximating to figure 3.31 and a.c. gain is X1.

100mV Range

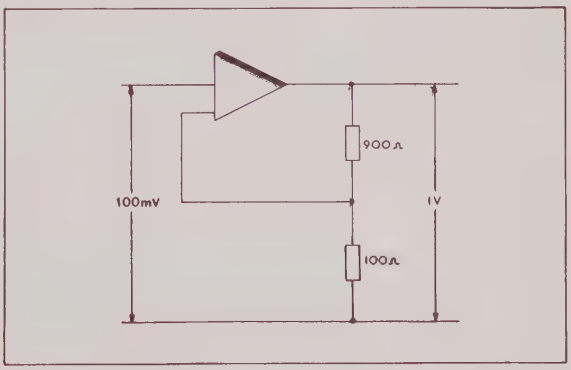


Figure 3.32 A.C. Amplifier - 100mV Range

Contact RLE/2 amends the feedback circuit to approximately that shown in figure 3.32. Since the voltage fed back is now one tenth of that shown in figure 3.31 the amplifier gain is increased by a factor of ten i.e. to X10.

Since the gain/bandwidth product of a feedback amplifier is constant, an increase in closed loop gain results in a reduced bandwidth and associated worsening of the high frequency response.

To maintain a similar high frequency performance with increased amplifier gain there must therefore be a corresponding increase in bandwidth and hence in the gain/bandwidth product.

This is achieved by increasing the gain of the input stage. Contact RLE/1, by short circuiting R10, increases the stage gain of the differential amplifier VT2, VT4 by approximately ten times. Closed loop gain, however, is unaffected and remains at X10. Since C15 is normally charged via R10, closure of RLE/1 produces no change in the d.c. circuit conditions.

10V Range

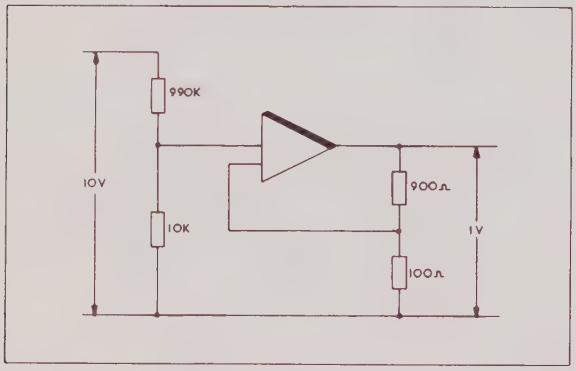


Figure 3.33 A.C. Amplifier - 10V Range

A.c amplifier gain is X10 defined, as before, by relay contact RLE/2. RLC/1 selects the input attenuator which reduces the input signal by a factor of 100 giving an overall gain of X0.1.

100V Range

The input attenuator selected by relay contact RLC/1 reduces the input signal by a factor of 100 while RLF/1 sets the a.c. gain of the amplifier to X1. Overall gain is thus X0.01.

750V Range

Relay contact RLD switches in the 1000:1 attenuator while RLF/1 sets the amplifier gain to X1. Overall gain is therefore X0.001.

Input Attenuator

High voltage input signals are routed via a 100:1 or 1000:1 attenuator. Fine adjustment at low frequencies is afforded by RV1 and RV2 while trimmers C16 and C17 provide high frequency adjustment.

AC Amplifier

Overload Protection

The attenuator output is coupled via the d.c. blocking capacitor C1 to an FET protection circuit in order to limit the peak input current [similar to that used for the 1604 input amplifier. Refer to section D.C. Filters - Out]. Protection from excessive voltage swings is provided by MR1 and MR2 which confine VT1 base voltage within the ±8 volt limits set by zener diodes MR3, MR4.

Frequency Response

In a closed loop amplifier minimum error between input and output signals exists when the open loop amplifier produces a 90^{o} phase shift. To achieve the required accuracy at high frequencies where the gain is low it is essential that the phase shift through the amplifier be maintained at 90^{o}. The feedback and compensation networks included in each stage of amplification ensure that this requirement is met over the specified frequency range of the instrument.

Input Stage

VT2 and VT4 with the constant current stage VT3 form a long-tailed pair amplifier. VT1 and VT2, VT5 and VT4 are connected as twin Darlington pairs which, together with the negative feedback network R4, R5 C5 ensure a very high input impedance. R2, connected in parallel with the input signal, defines the input impedance at 10MΩ. R8 and C5 are shaping components contributing to the overall a.c. amplifier response.

Intermediate Amplifier

The output from VT2 collector drives two conventional amplifying stages VT6 and VT7, feedback being applied via C12, R14 and C14, R17 to produce the required high frequency response. VT7 base is protected from large reverse voltages by MR6 while MR11, MR12 and R38 limit the collector current to that defined by R22. Excessive current when switching on which could flow through VT7 via R26 and VT8 base/emitter junction is blocked by MR11 and diverted through R38.

Output Stage

The output from VT7 is coupled via MR11, MR12 to the output amplifier VT8 which drives the demodulator consisting of MR8, MR9 and associated resistors. If, supplied from a voltage source, distortion due to the non-linear characteristic of the diodes would result in measurement errors. However, the constant current

stage, VT9, ensures that a sinusoidal current flows through the diodes and keeps distortion at a low level.

Feedback from VT9 collector is applied to the input stage via R19, R25.

Demodulator

The a.c. developed across R43 is rectified by MR8, MR9 and then applied to the filter network. The a.c. signal is re-constituted at the junction of R29, R33 and fed back to the input stage to control the amplifier gain.

Filter

General

The positive and negative-going portions of the rectified a.c. signal are smoothed separately by two identical filter networks. Since the LM 1604 voltmeter measures the differential voltage between the two halves of the filter, any demodulator unbalance will not effect measurement accuracy.

The filter has three positions selected by the push-buttons on the front panel.

Slow

Figure 3.34 shows one half of the balanced filter. Three RC networks give a response time of 10 seconds for measurement of a.c. between 15Hz and 50Hz.

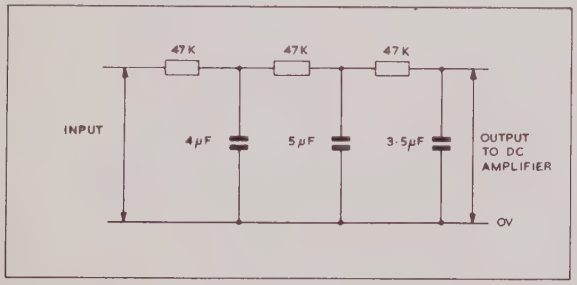


Figure 3.34 A.C. Response - 10s

Medium

Response time is reduced to 3 seconds which is adequate for a.c. between 50Hz and 350Hz.

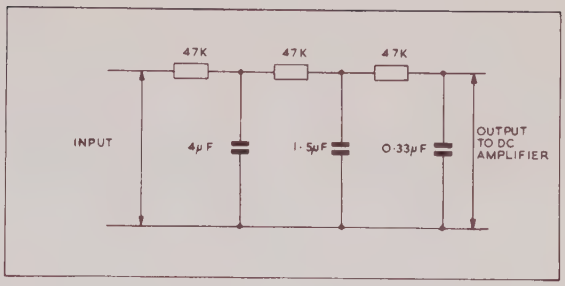


Figure 3.35 A.C. Response - 3s

Fast

The response time of 1 second makes this position suitable for a.c. above 350Hz.

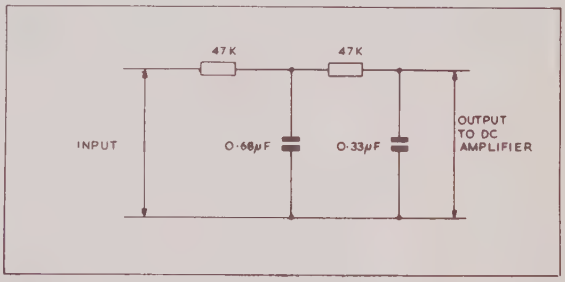
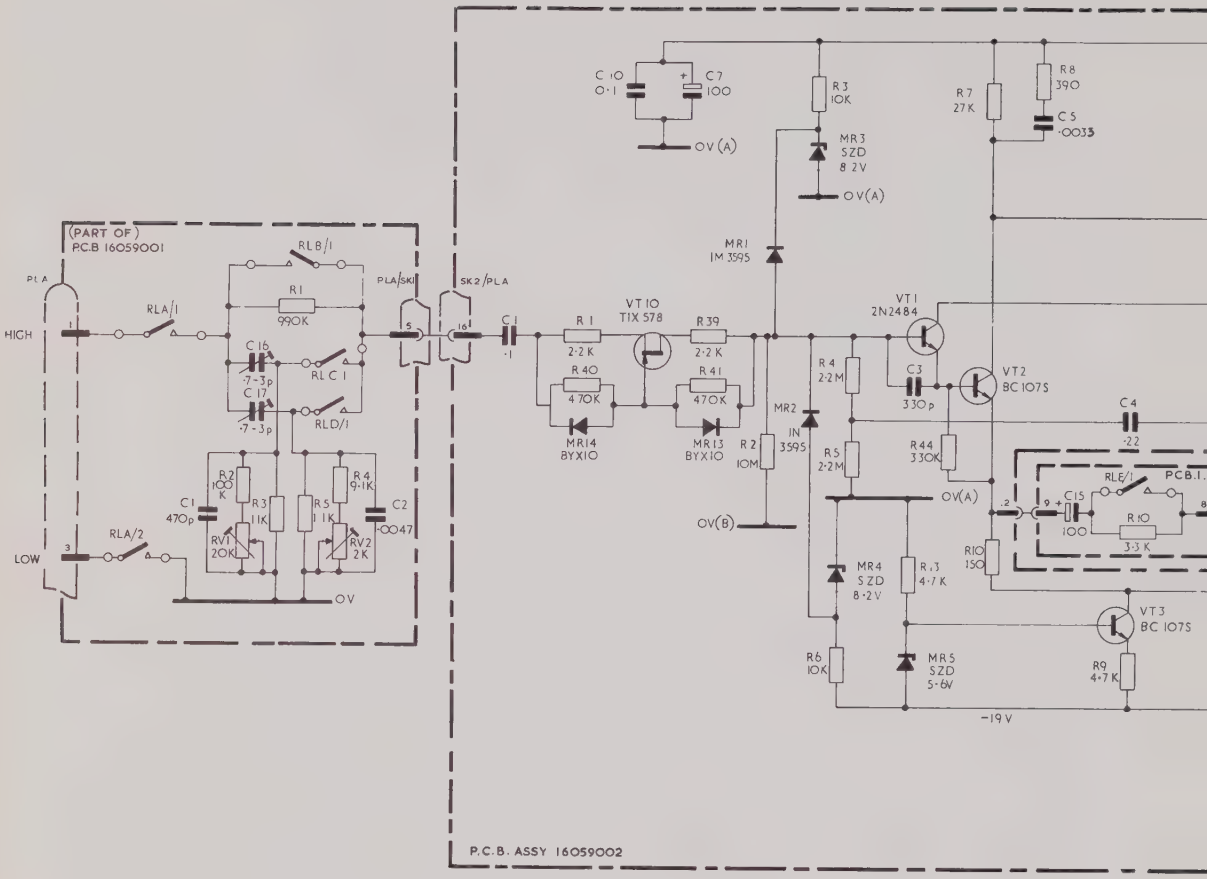
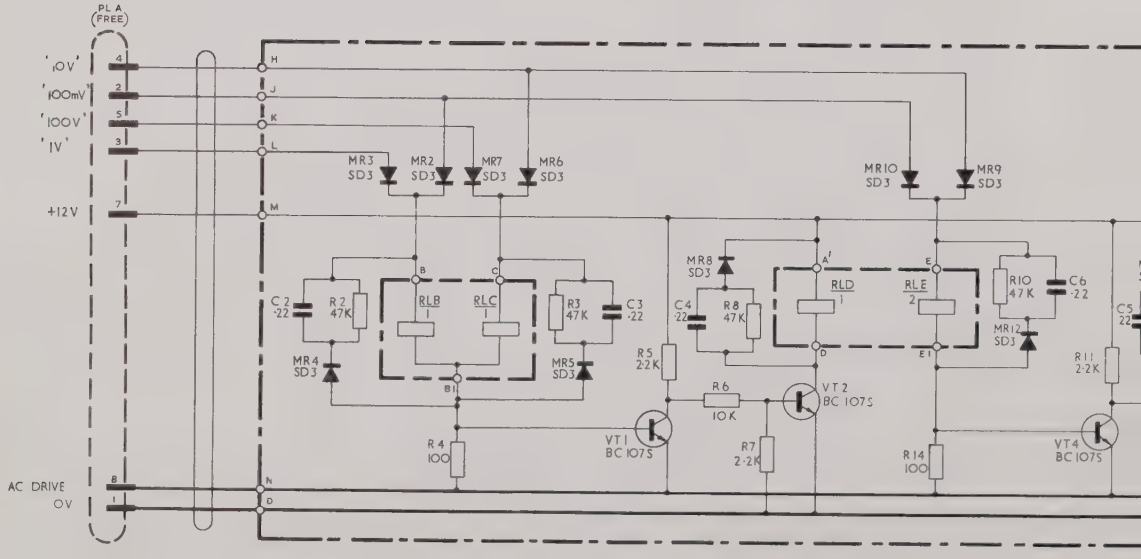
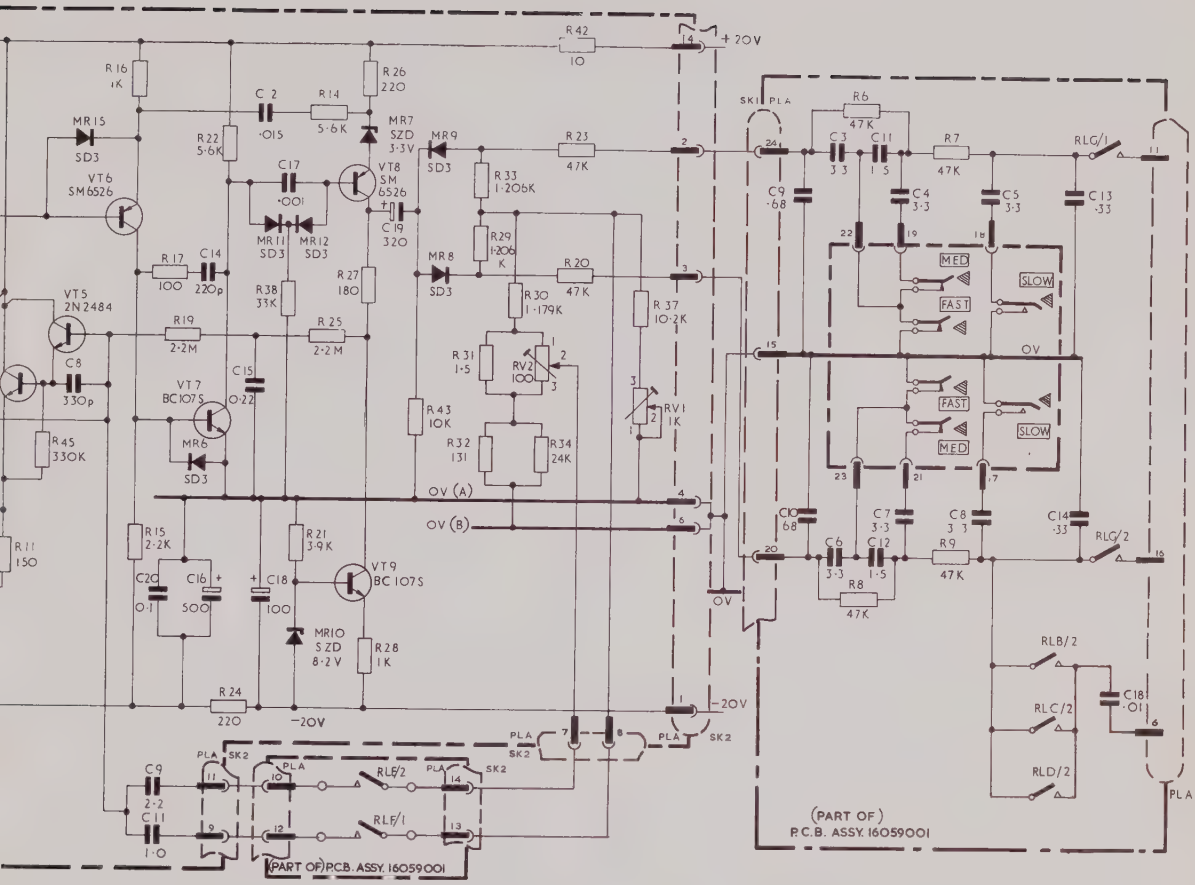
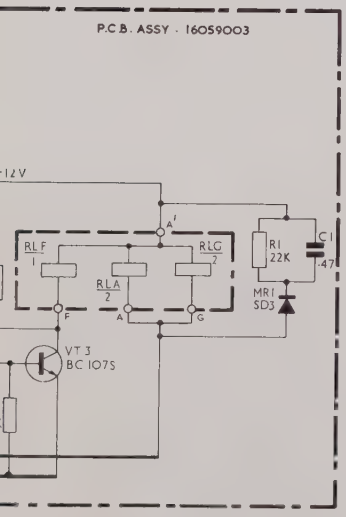


Figure 3.36 A.C. Response - 1s


(PART OF)
P.C.B 16059001
PLA
HIGH
LOW
RLA/1
RLA/2
RLB/1
RLC 1
RLD/1
R1
990K
C16
·7-3p
C17
·7-3p
R2
100K
R3
11K
R4
9·1K
R5
1K
C1
470p
C2
·047
RV1
20K
RV2
2K
OV
PLA/SK1
SK2/PLA
C1
·1
VT10
TIX 578
R1
2·2K
R39
2·2K
R40
470K
R41
470K
MR14
BYX10
MR13
BYX10
C10
0·1
C7
100
OV(A)
R3
10K
MR3
SZD
8·2V
MR1
IM 3595
MR2
IN
3595
R2
10M
OV(B)
VT1
2N2484
R4
2·2M
C3
330p
VT2
BC 107S
R44
330K
R5
2·2M
MR4
SZD
8·2V
R13
4·7K
R6
10K
MR5
SZD
5·6V
-19V
R7
27K
R8
390
C5
·0033
C4
·22
RLE/1
C15
100
R10
3·3K
R10
150
VT3
BC 107S
R9
4·7K
P.C.B. ASSY 16059002


PLA
(FREE)
'10V'
'100mV'
'100V'
'1V'
+12V
AC DRIVE
OV
MR3
SD3
MR2
SD3
MR7
SD3
MR6
SD3
MR10
SD3
MR9
SD3
MR8
SD3
MR12
SD3
MR4
SD3
MR5
SD3
C2
·22
R2
47K
RLB
1
RLC
1
R3
47K
C3
·22
C4
·22
R8
47K
RLD
1
RLE
2
R10
47K
C6
·22
R5
2·2K
R6
10K
R7
2·2K
R4
100
R14
100
R11
2·2K
VT1
BC 107S
VT2
BC 107S
VT4
BC 107S





NOTES:—

(1) EX1605. IS FITTED INTO LM1604 DC VOLTMETER. TO CONVERT THE INSTRUMENT TO LM1604/05 AC/DC VOLTMETER IN ADDITION, A NEW FRONT PANEL IS REQUIRED FOR LM1604 TO COMPLETE THE MODIFICATION.

(2) INTERCONNECTIONS BETWEEN P.C.Bs. ARE OBTAINED VIA THE 'MOTHER BOARD' SOCKETS SK1 & SK2 ON LM1604 (LM1603)

(3) PUSH BUTTON SWITCHES 'SLOW', 'MED' 'FAST' DO NOT FORM PART OF EX1605 MODULE THEY ARE FOR REF. ONLY.

01 27.8.69

EX1605 AC Kit
Board Nos 1, 2 and 3

D16057000

EX3055 AUTO RANGE BOARD

Introduction

The EX3055 is an optional plug-in board which, when fitted in the LM1604 display section, enables the voltmeter itself to select the range appropriate to the voltage applied to its input terminals. Operation is restricted to d.c. ranges 0-4, but a measurement may be initiated either manually or at 25/s.

Caution 1

When the auto-range mode is selected, the maximum voltage which may safely be applied to the voltmeter input terminals is 200V d.c. Voltages in excess of this may cause damage.

Caution 2

If the filter is switched in and a measurement sample is commanded manually, it will be necessary to sample more than once in order to obtain the correct reading, due to the time constant of the filter.

Range Decisions

The range selected depends upon the state of the BINARY COUNTER whose decoded output operates a decimal drive to energise the relevant LM1604 range relays. The counter is triggered by pulses from the AUXILIARY BISTABLE via the RANGE GATES.

Two gates examine the staticised outputs from the LM1604 display counter and present one of the following indications to the range gates:-

(a) That the display is equal to or greater than 1900. (up-range necessary).
(b) That the display is less than 1800 (down-range necessary), or,
(c) That the display lies between the above limits.

From this information, the range gates decide whether it is necessary to change to a different range and whether such a change should increase or reduce the voltmeter sensitivity.

When no range change is required, trigger pulses from the auxiliary bistable are inhibited by the range gates and

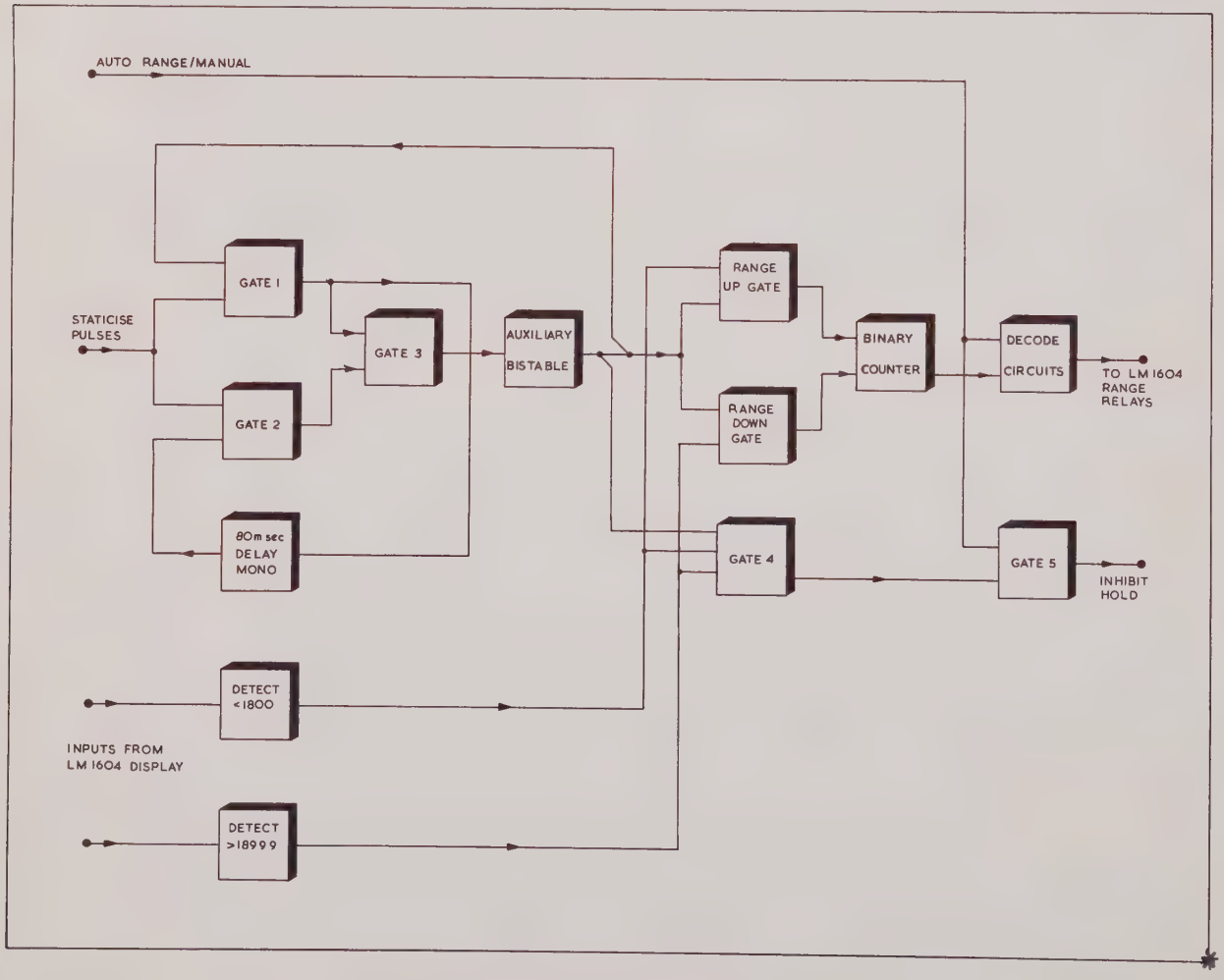


Figure 3.37 EX3055 Block Diagram

the counter remains static. If a down-range is indicated, each pulse from the auxiliary bistable steps the counter on once thereby increasing the voltmeter sensitivity by one range at a time. This process continues until the gates indicate that no further range change is necessary.

If an up-range is required, the first pulse from the auxiliary bistable sets the counter to zero, thus selecting the 100V range, which is the least sensitive auto range. If the input signal is less than 18 Volts, range down information will then be set. Each subsequent pulse steps the counter on once and the voltmeter down-ranges until the logic again indicates that the correct range has been achieved. If the input signal lies between 18 Volts and 190.00 Volts, no further range change command is generated.

If the input signal exceeds 190.00 Volts, a further up-range signal is generated. This is rejected by the counter because it is set to the limit of its range.

Auxiliary Bistable

At the end of the first measurement cycle after a sample has been initiated, the staticise pulse from the LM1604 opens GATES 1 and 2. The leading edge of the output from gate 1 triggers the 80 msec. DELAY MONOSTABLE. The monostable output then closes gate 2 for the whole of the delay period.

When the staticise pulse ends, gate 1 closes allowing GATE 3 to open and toggle the auxiliary bistable, whose output then holds gate 1 inhibited. Further staticise pulses have no effect since both gates 1 and 2 are closed.

At the end of the delay period when the delay monostable reverts back to its rest state, the inhibit is removed from gate 2. The next staticise pulse to arrive passes via gate 2, closing gate 3. When this staticise pulse ends, gate 3 is re-opened and again toggles the auxiliary bistable removing the inhibit from gate 1. The next staticise pulse opens both gates 1 and 2, and the sequence re-commences.

The auxiliary bistable thus supplies a pulse to the range gates approximately once every 160 msecs., which allows the voltmeter ample settling time between range changes.

Inhibit Hold

The outputs from the DETECT 1800 and 19000 GATES together with the auxiliary bistable output are examined by GATE 4. When the auxiliary bistable delay has been completed and the logic is satisfied that the display is correct, gate 4 supplies one input to GATE 5. Providing that the auto-range mode has been selected, the latter closes removing the inhibit hold signal. This enables the next staticise pulse to generate a print command edge for recording purposes. (In the 25/s mode, the print command line is inoperative, hence this function is only available when manual sampling).

Auto Range/Manual Operation

When AUTO range is not selected, no outputs from the EX3055 are available since both gate 5 and the counter decode circuits are inhibited.

CIRCUIT DESCRIPTION

Range Change Decisions

19000 Gating

Edge connector pins 2, 11 and 3 respectively are energised from the $\overline{10\ 000}$, $\overline{8}_3$ and $\overline{1}_3$ display counter bistable outputs. When the displayed reading reaches or exceeds 19000, the inputs to inverters IC1d, e and f are thus LOW opening NAND gate IC2b. The LOW output from IC2b is inverted by IC1a whose output therefore remains HIGH until the display registers less than 19000. Hence IC1a pin 2 is HIGH if the reading is greater than or equal to 19000.

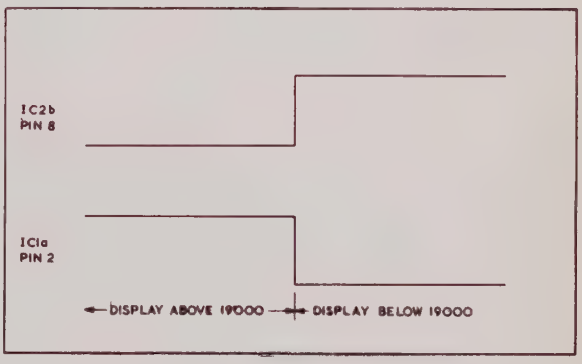


Figure 3.38 Detect 19000 Gate

1800 Gating

Providing that the 1_3 and 8_2 display counter bistables are not both set, NAND gate IC3c will remain closed, applying a HIGH to IC2a pin 2. Should both bistables be set, however, a LOW will be present at edge connector pins 3 and 12. Inverters IC1b and e will each apply a HIGH to IC3c which will open and inhibit IC2a.

The other four inputs to IC2a are derived from the

10 000 bistable and the $\overline{8}_3$, $\overline{4}_3$ and $\overline{2}_3$ display counter bistables. For the gate to open, these inputs must all be HIGH with IC3c closed - a condition which can only occur if the displayed reading is less than 1800. IC1c inverts the LOW output from the opened IC2a. Hence IC1c pin 6 is HIGH if the reading is less than 1800.

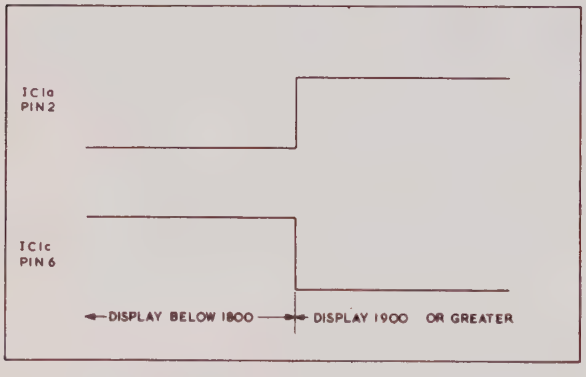


Figure 3.39 Detect 1800 Gate

Note. For normal use, as described previously, the following links must be made: Links LKA, LKD, and LKF. When used with the Solartron Compact Series Two Logger or in any application where different range limits are required, the following links must be made: Links LKB, LKC, LKE and LKG. Range changes will consequently occur at upper and lower limits of 9000 and 799 respectively.

Auxiliary Bistable

When either the MANUAL sample or 25/s push-button is pressed the HOLD BISTABLE (on LM1604 Board 2) is set and a staticise pulse is generated at the end of the digitisation cycle. Assuming that IC10 is initially in the set condition, (i.e. pin 9 is HIGH) then IC11b pin 5 will be HIGH. Since the delay monostable VT1, VT2 is at rest with VT2 conducting, VT3 is cut off. This applies a HIGH to IC11a pin 1. When the positive-going staticise pulse provides the second HIGH input to IC11a and b, both gates open thereby closing IC11c

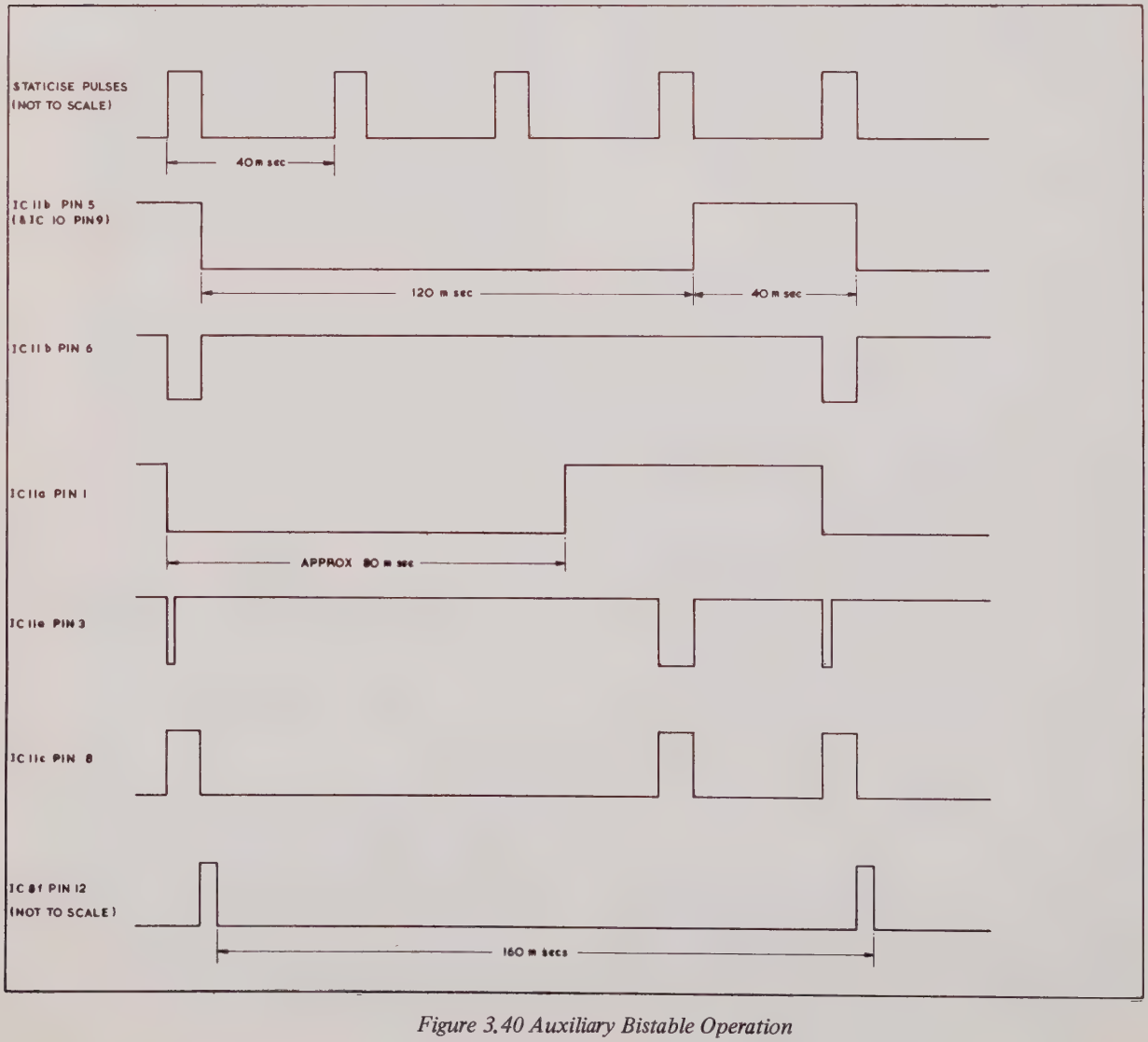


Figure 3.40 Auxiliary Bistable Operation

which applies a positive edge to IC10 pin 2. The auxiliary bistable is unaffected by this edge. The negative-going edge from IC11b pin 6 triggers the delay monostable causing the output of VT3 to go LOW. This is applied to IC11a pin 1. IC11a closes supplying one HIGH input to IC11c pin 9. IC11c remains closed because of the LOW remaining on pin 10. When the staticise pulse returns to the LOW state, IC11b closes causing IC11c pin 10 to go HIGH. IC11c pin 8 goes LOW and applies a negative-going edge to IC10 pin 2. The auxiliary bistable is triggered by this edge and IC10 pin 9 goes LOW. C1, R1 and R2 differentiate this edge and apply a negative-going 22μsec. pulse to inverter IC8f.

The output of IC8f pin 12 is a short positive-going pulse, the trailing edge of which provides the trigger pulse for the range counter.

IC11b is held closed by the LOW present on pin 5 derived from the auxiliary bistable. IC11a is closed by the LOW from VT3 collector present on pin 1. Hence, further staticise pulses are prevented from operating the auxiliary bistable until the delay monostable reverts to the rest condition after approximately 80msec. At this point, VT3 removes the inhibiting LOW from IC11a pin 1 and the next staticise pulse to arrive opens gate IC11a making IC11c pin 9 LOW. IC11c pin 8 therefore goes HIGH. When this staticise pulse ends, IC11a pin 3 goes HIGH when pin 2 goes LOW. As IC11a pin 10 is set HIGH, IC11a pin 8 goes LOW. The auxiliary bistable is thus again toggled and assumes its original state, i.e. pin 9 HIGH. This condition will exist until the arrival of the next staticise pulse when the sequence illustrated in figure 3.40 will be repeated.

Range Counter

General

The outputs from the three stage binary counter IC5-IC7 via appropriate decoding networks and power amplifiers, control the selection of the LM1604 range relays. The setting of the counter is determined both by the pulses from IC8f and by the outputs from the 1800 and 19000 gating networks. The state of the counter for the five auto ranges which it is possible to select are summarised in table 3.6.

RANGE SELECTED		PIN 9		BINARY NO. IN COUNTER
	IC5	IC6	IC7	
0 10mV	HIGH	LOW	LOW	4
1 100mV	LOW	HIGH	HIGH	3
2 1V	LOW	HIGH	LOW	2
3 10V	LOW	LOW	HIGH	1
4 100V	LOW	LOW	LOW	0

Table 3.6 Range Counter Code

[The outputs at pins 6 of the counter bistables are the complements of those shown in the table for pins 9].

Figure 3.41 is derived from figures 3.38 and 3.39 and depicts the three possible display conditions which can be detected by the gating circuits i.e.
[a] 19000 or greater,
[b] less than 1800,
[c] between the above two limits.

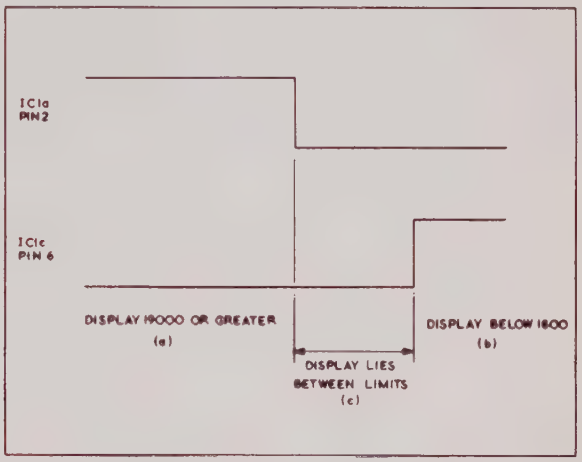


Figure 3.41 Range Gates Operation

No Range Change Required

Consider first, condition [c]. The outputs from both gates are LOW. Thus IC9c pin 10 is LOW and no trigger pulses can pass through IC9c to reset the counter. IC7 pins 3 and 12 are LOW and trigger pulses arriving at IC7 pin 2 have no effect. Hence the counter will remain in its existing state and no range change commands will be given to the voltmeter.

Down Range Decision

When condition [b] occurs, greater accuracy can be obtained by changing to a more sensitive range on the voltmeter [down-ranging]. From figure 3.41, IC1a pin 2 and hence IC9c pin 10 are LOW. Trigger pulses cannot therefore pass through IC9c to reset the counter. Since IC1c pin 6, and therefore IC7 pins 3 and 12, are HIGH, the negative-going edges of the pulses from IC8f pin 12 toggle bistable IC7. The outputs from IC5-IC7 are examined by the decoding logic and the next most sensitive range on the voltmeter will be selected.

After the next sample, if the reading on the display is still less than 1800, then the preceding sequence will be repeated - IC7 being toggled as before. IC5-IC7 form a ripple-through binary counter. From a consideration of table 3.6, if the counter starts initially from zero (i.e. the 100V range), then each successive pulse from IC8f will add in one bit and sequentially step the counter and voltmeter through the five available auto ranges.

Should the displayed reading on the final range (10mV) still be less than 1800, then the LOW present at IC5 pin 6 causes IC9d pin 11 to go HIGH. This causes a LOW output from IC8b pin 4 which clamps IC6 and IC7 such that their outputs on pin 9 are LOW. Further pulses from IC8f therefore have no effect on the counter and the voltmeter will remain switched to the 10mV range.

Up Range Decision

When condition [a] occurs, the voltmeter is command to switch to a less sensitive range [up-ranging]. From figure 3.41, IC1c pin 6 and hence IC7 pins 3 and 12 are LOW. This prevents trigger pulses from IC8f triggering IC7. However, the HIGH on IC9c pin 10 from IC1a pin 2 allows the pulses from IC8f to pass through IC9c. Irrespective of the range to which the voltmeter happens to be set, it is reset to the least sensitive auto range (100V) by this pulse as follows. When IC9c pin 8 goes LOW it causes IC5 pin 9 to be set to LOW. At the same time IC9d pin 11 will go HIGH causing IC8b pin 4 to go LOW. This causes IC6 and IC7 pin 9 to be set to LOW. Thus, from table 3.6, the counter is set to select the 100V range relay.

Should subsequent displayed readings still indicate greater than 19000 the voltmeter will remain on the 100V range.

If subsequent readings are below 1800 the sequence for range down is followed until no further range change is required.

Auto/Manual Decision

General

The five states of the counter are decoded to provide decimal drive to transistors VT4 to VT8.

Arrangements are made to ensure than none of these transistors can be switched on when the auto range mode has not been selected.

Manual Range Changing

When it is required to select ranges manually, switch wafer SA16 of the AUTO switch is open and edge connector pin 18 of the EX3055 is open-circuited or HIGH. The HIGH at pin 5 of IC8c is inverted and overrides IC8a output to hold off VT8. Similarly, IC9a output prevents VT4 from conducting.

Note Where two gate outputs are wired together, a LOW output demand overrides a HIGH output demand

The output from IC8d is LOW. Hence, IC4c output will be HIGH. This output is inverted by IC8e to cut off VT7. IC11d is similarly forced to provide a HIGH output and this is inverted both by IC12a and c to cut off VT5 and 6. Thus, under these conditions, no range can be automatically selected by the EX3055.

Auto Range Change

Depression of the AUTO range switch applies a LOW to IC8d pin 9, IC8c pin 5 and IC9a pin 1. IC8a and IC9b now control VT8 and VT4 bases. The HIGH output from IC8d is applied to IC4c pin 11 and IC11d pin 13 and control of transistors VT5 - VT7 depends on the state of the counter IC5-IC7.

Counter Decoding

100V Range

Pins 3, 4 and 5 of IC4b are all HIGH when pins 6 of IC5 - IC7 are HIGH - a condition occuring only when the counter registers binary 0 [refer to table 3.6]. IC8a inverts the LOW output from IC4b applying a HIGH to VT8 base via MR11 and energising the 100V range relay.

10V Range

IC4c goes LOW when the auto range mode is selected and the counter applies a HIGH to pins 9 and 10. From table 3.6, this occurs only when the counter registers binary 1. The LOW from IC4c is inverted by IC8e and switches on VT7, energising the 10V range relay.

1V Range

When the counter registers binary 2, IC7 pin 9 is LOW and VT6 is controlled by IC12a. Providing that IC6 pin 9 is HIGH and that the auto-range mode has been selected, IC11d output will be LOW. IC12a pin 2 will be HIGH causing VT6 to energise the 1V range relay. From table 3.6 these conditions are satisfied only when the counter has stored binary 2.

100mV Range

When the counter register binary 3, IC7 pin 6 is LOW and VT5 is controlled by IC12c. If the auto-range mode is selected, with IC6 pin 9 HIGH and IC11d pin 11 LOW, this causes IC12c output to be HIGH turning on VT5 and energising the 100mV range relay. From table 3.6, these conditions are satisfied only when the counter has stored binary 3.

10mV Range

When auto range is selected IC9a pin 1 is LOW and VT4 is controlled by IC9b. When binary 4 is registered in the counter, IC5 pin 6 is LOW. This causes the output of IC9b to be HIGH turning on VT4 which energises the 10mV range relay via VT4. The counter is arranged such that it is never possible to obtain higher than binary 4.

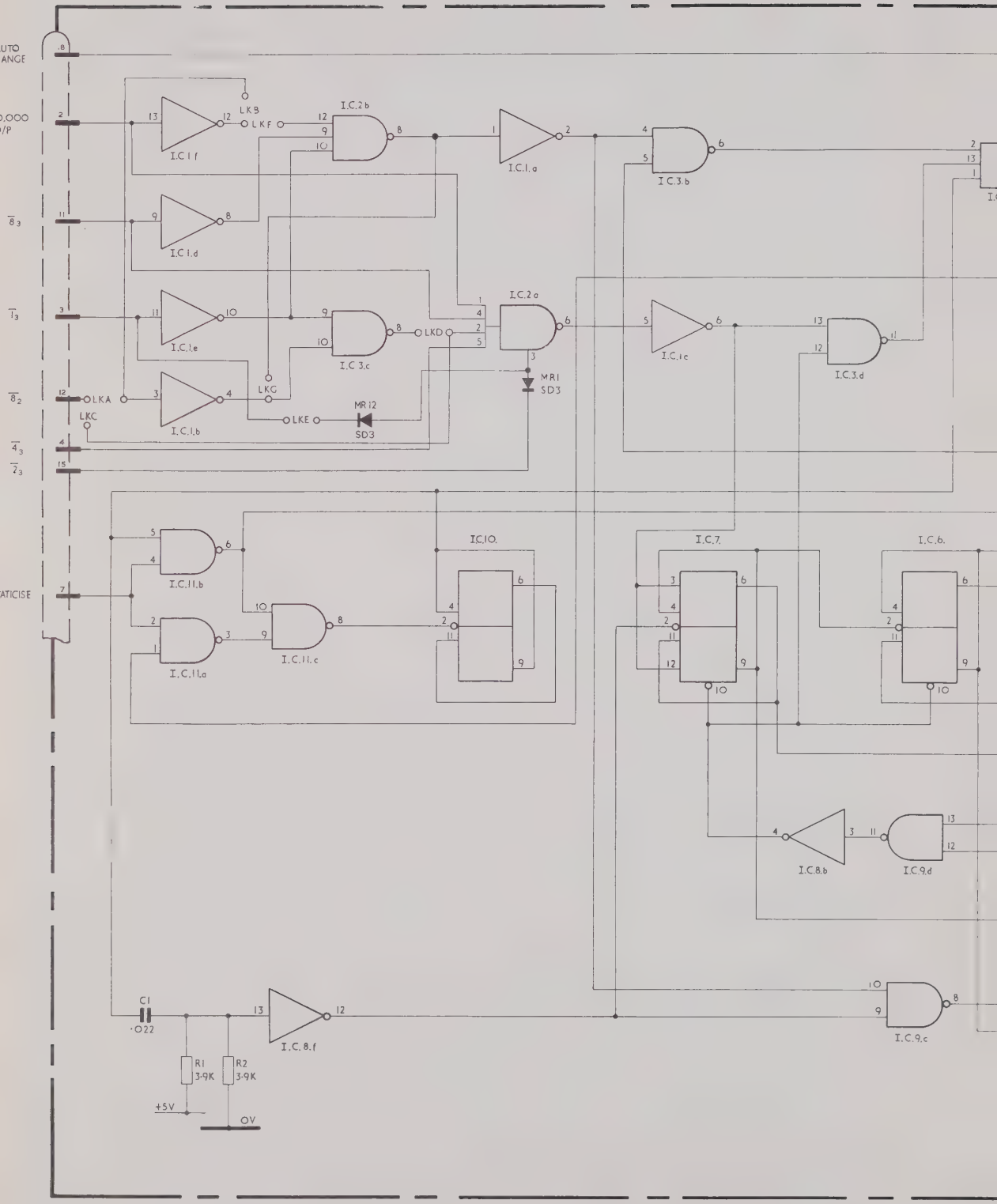
Inhibit Hold And Print Commands

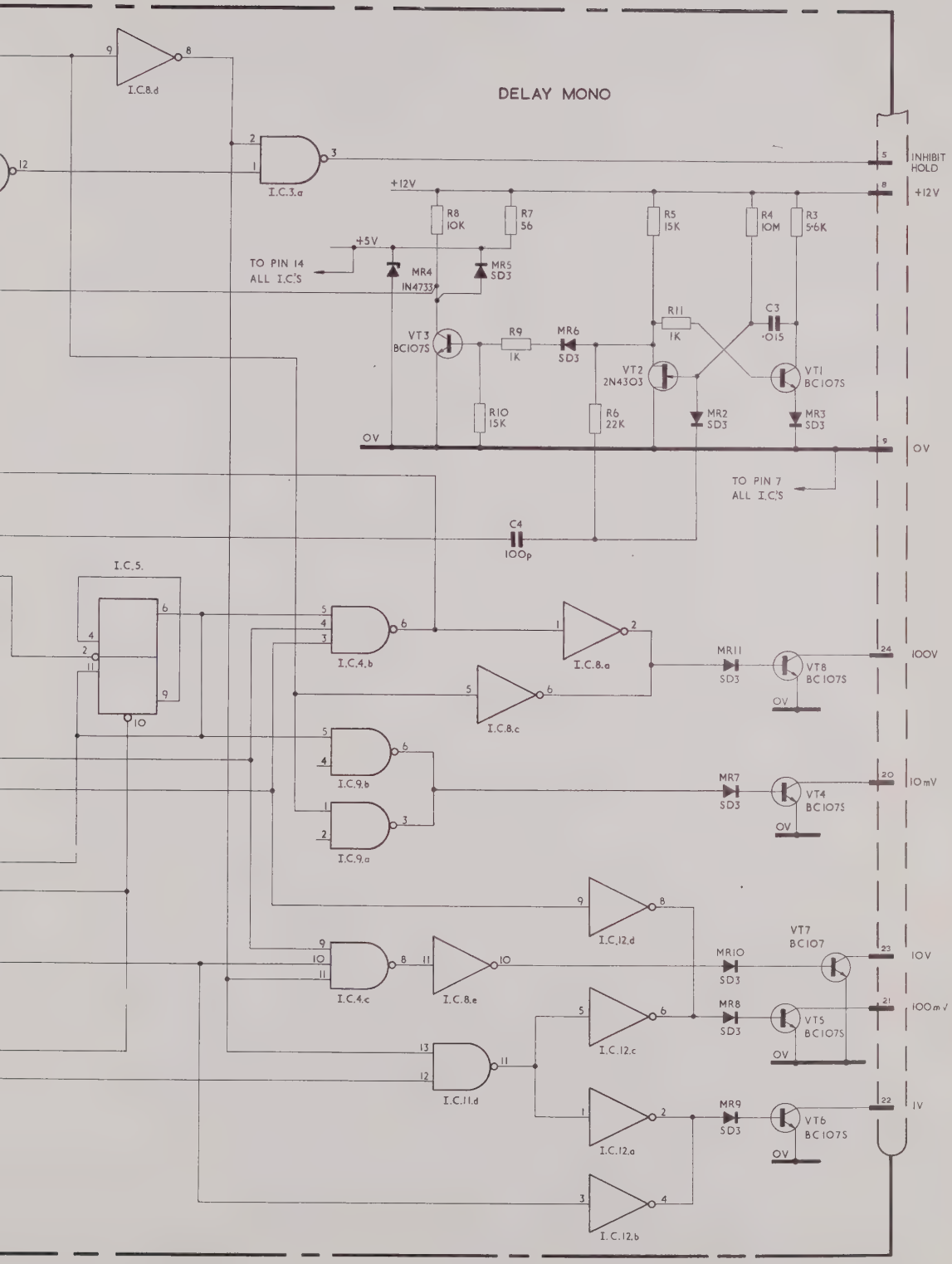
If Auto Range is called, IC8d pin 9 is LOW, and its output pin 8 is HIGH. If either pin 1, pin 2 or pin 13 of IC4a is LOW, IC4a pin 12 is HIGH. IC3a pin 3 is then LOW. This prevents the read bistable on the LM1604

board 2 from resetting the hold bistable, and permits the LM1604 to start the next digitisation cycle. No print command is generated. IC4a pin 1 is LOW if the auxiliary bistable has been set by the delay monostable. IC4a pin 2 is LOW if an up range is required and the existing range is not the 100 Volt range. IC4a pin 13 is LOW if a down range is required and the existing range is not the 10mVolt range. Hence, the output of IC3a pin 3 will remain LOW until the final range is achieved and the delay set by the monostable and auxiliary bistable is ended. The first read pulse after the resetting of the auxiliary bistable will reset the hold bistable and no further staticise pulses will occur until the next sample is commanded. If the 25/sec. mode is selected, the hold bistable is permanently set and no reset pulses are required. The inhibit hold line is thus inoperative and the LM1604 works in its conventional manner.

If ranges are selected manually, then a print command signal will be issued at the end of each digitisation cycle.

No print commands will be generated in the 25/sec. mode [refer to 'Print Command Signals'.]


UTO
ANGE
,000
/P
$\overline{8}_3$
$\overline{1}_3$
$\overline{8}_2$
$\overline{4}_3$
$\overline{2}_3$
ATICISE
LKB
LKF
I.C.2 b
I.C.1 f
I.C.1.a
I.C.3.b
I.C.1.d
I.C.2 a
I.C.1.e
I.C 3.c
LKD
I.C.1.c
I.C.3.d
LKA
LKC
LKG
LKE
MR12
SD3
MR1
SD3
I.C.1.b
I.C.11.b
I.C.11.a
I.C.11.c
IC.10.
I.C.7.
I.C.6.
I.C.8.b
I.C.9.d
C1
·022
R1
3·9K
R2
3·9K
+5V
0V
I.C.8.f
I.C.9.c


DELAY MONO
I.C.8.d
I.C.3.a
INHIBIT HOLD
+12V
R8 10K
R7 56
R5 15K
R4 10M
R3 5·6K
+5V
TO PIN 14 ALL I.C'S
MR4 IN4733
MR5 SD3
R11 1K
C3 ·015
VT3 BC107S
R9 1K
MR6 SD3
VT2 2N4303
VT1 BC107S
R10 15K
R6 22K
MR2 SD3
MR3 SD3
OV
TO PIN 7 ALL I.C'S
C4 100p
I.C.5.
I.C.4.b
I.C.8.a
I.C.8.c
MR11 SD3
VT8 BC107S
100V
I.C.9.b
I.C.9.a
MR7 SD3
VT4 BC107S
10mV
I.C.12.d
I.C.4.c
I.C.8.e
VT7 BC107
MR10 SD3
10V
I.C.12.c
MR8 SD3
VT5 BC107S
100mV
I.C.11.d
I.C.12.a
MR9 SD3
VT6 BC107S
1V
I.C.12.b

02 11 11 69

FAN OUT UNITS

General

A choice of two fan out units is provided, permitting the remote control of the voltmeter from either positive or negative logic command signals.

High level, staticised outputs, tolerant of supply variations and noise are available indicating the polarity and value of the measured voltage in BCD form. Certain other functions for data logging applications are also made available [e.g. print command].

POSITIVE LOGIC FAN OUT UNIT EX3054

Introduction

The unit consists of two printed circuit boards, one of which provides buffer stages between the voltmeter and the system in which it is to be used, while the second is used for commanding range and mode of operation.

Board 1

Counter Outputs

The information stored by the counter memory bistables and the 10 000 bistable on board 2 is transferred to pins 1-17 of PLA by the staticise pulse. A LOW signifying that a particular bit of information has been stored, will switch off the associated transistor and produce a HIGH at at the collector. Thus, the staticised counter outputs appear appear at SKA/A-U with a HIGH indicating the bits stored.

Print Command

Print command signals from the voltmeter are applied to VT21 base via PLA pin 20. After inversion by VT21 and again by VT23 an output is provided at SKA/v.

Digitise Command

Staticisation is commanded by applying a positive pulse to SKA/t to fire the Schmitt Trigger VT15, VT17. VT19 is switched on by VT17 and, providing both 25/s and MANUAL push-buttons are released, one staticise pulse will be generated during the next measurement cycle to update the display.

Contact Sample

VT19 collector is connected to SKA/s. If a digitise command pulse is not available, staticisation may be commanded by, for example, a relay contact connected between sockets s and HH.

Gated Clock

The 1MHz counter input pulses generated during the ramp up period and the 2MHz pulses occuring during ramp down are applied to VT12 base via PLA pin 34. VT12 provides a positive-going gated clock pulse output at SKA/CC.

Direct Polarity

When a positive polarity input is applied to the voltmeter, VT9 is held off by the permanent LOW at PLA pin 29. [Refer to figure 3.20] SKA/AA will therefore remain at a permanent HIGH.

A negative polarity input will result in the direct polarity waveform of figure 3.22 being applied to VT9 base giving an inverted output at SKA/AA.

Polarity information is available at the end of the ramp up period. [Refer to figures 3.20 and 3.22].

Staticised Polarity

A positive polarity voltmeter input will cause a HIGH to be applied to PLA pin 18 after a staticise pulse has occurred. The output from inverter VT2 will therefore be a LOW and is connected to SKA/e. At the same time, VT2 output is inverted by VT4 and a HIGH will be present at SKA/d.

When a negative voltage is being measured, the levels at SKA/e and d will be HIGH and LOW respectively.

Since these are staticised outputs, polarity information is not available until the beginning of the drift correct period [refer to figure 3.25].

Ramp Up

The $\overline{\text{RAMP UP}}$ output from the slave ramp up bistable is applied to VT6 base. The output at SKA/DD is thus a HIGH during the ramp up period.

Board 2

A.C. Sub Unit Command

Provided that the REMOTE push-button SJ2 is depressed, a HIGH applied to SKA/r switches on VT1 and VT2. VT2 collector is connected to +12 volts via R2 on LM1604 board 9 and the consequent output at pin 27 of PLA is a LOW enabling the a.c. range relays to be energised. [Refer to 'Range Switching and Mode Selection'] VT7 is switched off via MR3 and the HIGH fed to SKA/k signifies that a.c. operation has been commanded.

Should the REMOTE push-button SJ2 not be selected, a LOW is applied to PLA pin 33. This inhibits any a.c. commands by clamping the junction of R1, R2 to 0 volts via MR1.

When no a.c. command is present on SKA/r, VT1 and

VT2 are switched off. PLA pin 27 is freed and d.c. ranges may be called.

B.C.D. Range Commands

Any a.c. or d.c. range can be remotely selected by applying a BCD range command to SKA/m, n, and p.

The BCD inputs are decoded on to seven lines. Diode/Resistor AND gates detect 0-5 or 7 and drive transistors whose outputs energise the a.c. or d.c. range relays required. NAND gates encode the decimal relay drive back to BCD to provide an indication of the range in use at SKA/f, h and j.

A binary 7 range input energises none of the range relays but commands the Autorange mode in which, if an Autorange board EX3055 is fitted, d.c. range selection is automatic.

Binary to Decimal Decode

A HIGH, signifying binary 1, applied to SKA/m, switches on VT8 and the LOW on VT8 collector switches off VT10. The $\overline{1}$ and 1 lines in the diode decode network are thus LOW and HIGH respectively. Similarly, the $\overline{2}$ and 2 lines are LOW and HIGH respectively when a binary 2 input switches on VT4.

The $\overline{4}$ and 4 lines are driven from transistors VT9 and VT11. VT3 and VT5 with diodes MR4 and MR5 provide protection should no binary inputs be present at SKA. Assuming that range 4 is called, the HIGH at SKA/p switches on VT3 and consequently VT5. MR4 is reverse biased by the LOW from VT5 collector but MR5 conducts applying a HIGH to VT9 base. The $\overline{4}$ and 4 lines are therefore LOW and HIGH respectively. When range 4 is not called and SKA/p is a LOW, VT3 still conducts but its emitter will now be LOW. VT5 base is still biased positively and the transistor remains on. Since both MR4 and MR5 anodes are now LOW, VT9 is cut off and the $\overline{4}$ and 4 lines revert to HIGH and LOW respectively.

Suppose, now, that no inputs are applied to any of the BCD range command sockets - a condition which could occur with a failure in the external drive circuitry. VT3 base is floating and the transistor does not conduct. Its emitter, therefore, will be at -12 volts cutting off VT5. MR5 is reverse biased but the HIGH from VT5 collector is passed via MR4 and VT9 base and the $\overline{4}$ and 4 lines are LOW and HIGH respectively. Range 4 [200V F.S.D.] is called under these conditions ensuring that the voltmeter is switched to a range where damage is unlikely.

BCD INPUT	HIGH LINES	AND GATE OPEN	TRANSISTORS SWITCHED ON	RANGE CALLED	SKA pins HIGH
All lines open Circuit	$\overline{1}$ $\overline{2}$ $\overline{4}$	MR31 - 34	VT18, VT14 VT16	4 [100V]	j
0	$\overline{1}$ $\overline{2}$ $\overline{4}$	MR8 - 11	VT12, VT14 VT16, VT19	0 [10mV]	NONE
1	1 $\overline{2}$ $\overline{4}$	MR12 - 15	VT13, VT16 VT19	1 [100mV]	f
2	$\overline{1}$ 2 $\overline{4}$	MR20 - 23	VT15, VT14 VT19	2 [1V]	h
3	1 2 $\overline{4}$	MR27 - 30	VT17, VT19	3 [10V]	f, h
4	$\overline{1}$ $\overline{2}$ 4	MR31 - 34	VT18, VT14 VT16,	4 [100V]	j
5	1 $\overline{2}$ 4	MR38 - 41	VT20, VT16	5 [1000V]	f, j
6	1 2 4	NONE	VT14, VT16 VT19	NONE	NONE
7	1 2 4	MR42 - 45	VT21	AUTO	f, h, j

Table 3.7 · BCD–Decimal Decode

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Digitise Command

Staticisation is commanded by applying a positive pulse to SKA/t to fire the Schmitt Trigger VT15, VT17. VT19 is switched on by VT17 and, providing both 25/s and MANUAL push-buttons are released, one staticise pulse will be generated during the next measurement cycle to update the display.

Contact Sample

VT19 collector is connected to SKA/s. If a digitise command pulse is not available, staticisation may be commanded by, for example, a relay contact connected between sockets s and HH.

Gated Clock

The 1MHz counter input pulses generated during the ramp up period and the 2MHz pulses occuring during ramp down are applied to VT12 base via PLA pin 34. VT12 provides a positive-going gated clock pulse output at SKA/CC.

Direct Polarity

When a positive polarity input is applied to the voltmeter, VT9 is held off by the permanent LOW at PLA pin 29. [Refer to figure 3.20] SKA/AA will therefore remain at a permanent HIGH.

A negative polarity input will result in the direct polarity waveform of figure 3.22 being applied to VT9 base giving an inverted output at SKA/AA.

Polarity information is available at the end of the ramp up period. [Refer to figures 3.20 and 3.22].

Staticised Polarity

A positive polarity voltmeter input will cause a HIGH to be applied to PLA pin 18 after a staticise pulse has occurred. The output from inverter VT2 will therefore be a LOW and is connected to SKA/e. At the same time, VT2 output is inverted by VT4 and a HIGH will be present at SKA/d.

When a negative voltage is being measured, the levels at SKA/e and d will be HIGH and LOW respectively.

Since these are staticised outputs, polarity information is not available until the beginning of the drift correct period [refer to figure 3.25].

Ramp Up

The $\overline{\text{RAMP UP}}$ output from the slave ramp up bistable is applied to VT6 base. The output at SKA/DD is thus a HIGH during the ramp up period.

Board 2

A.C. Sub Unit Command

Provided that the REMOTE push-button SJ2 is depressed, a HIGH applied to SKA/r switches on VT1 and VT2. VT2 collector is connected to +12 volts via R2 on LM1604 board 9 and the consequent output at pin 27 of PLA is a LOW enabling the a.c. range relays to be energised. [Refer to 'Range Switching and Mode Selection'] VT7 is switched off via MR3 and the HIGH fed to SKA/k signifies that a.c. operation has been commanded.

Should the REMOTE push-button SJ2 not be selected, a LOW is applied to PLA pin 33. This inhibits any a.c. commands by clamping the junction of R1, R2 to 0 volts via MR1.

When no a.c. command is present on SKA/r, VT1 and

VT2 are switched off. PLA pin 27 is freed and d.c. ranges may be called.

B.C.D. Range Commands

Any a.c. or d.c. range can be remotely selected by applying a BCD range command to SKA/m, n, and p.

The BCD inputs are decoded on to seven lines. Diode/Resistor AND gates detect 0-5 or 7 and drive transistors whose outputs energise the a.c. or d.c. range relays required. NAND gates encode the decimal relay drive back to BCD to provide an indication of the range in use at SKA/f, h and j.

A binary 7 range input energises none of the range relays but commands the Autorange mode in which, if an Autorange board EX3055 is fitted, d.c. range selection is automatic.

Binary to Decimal Decode

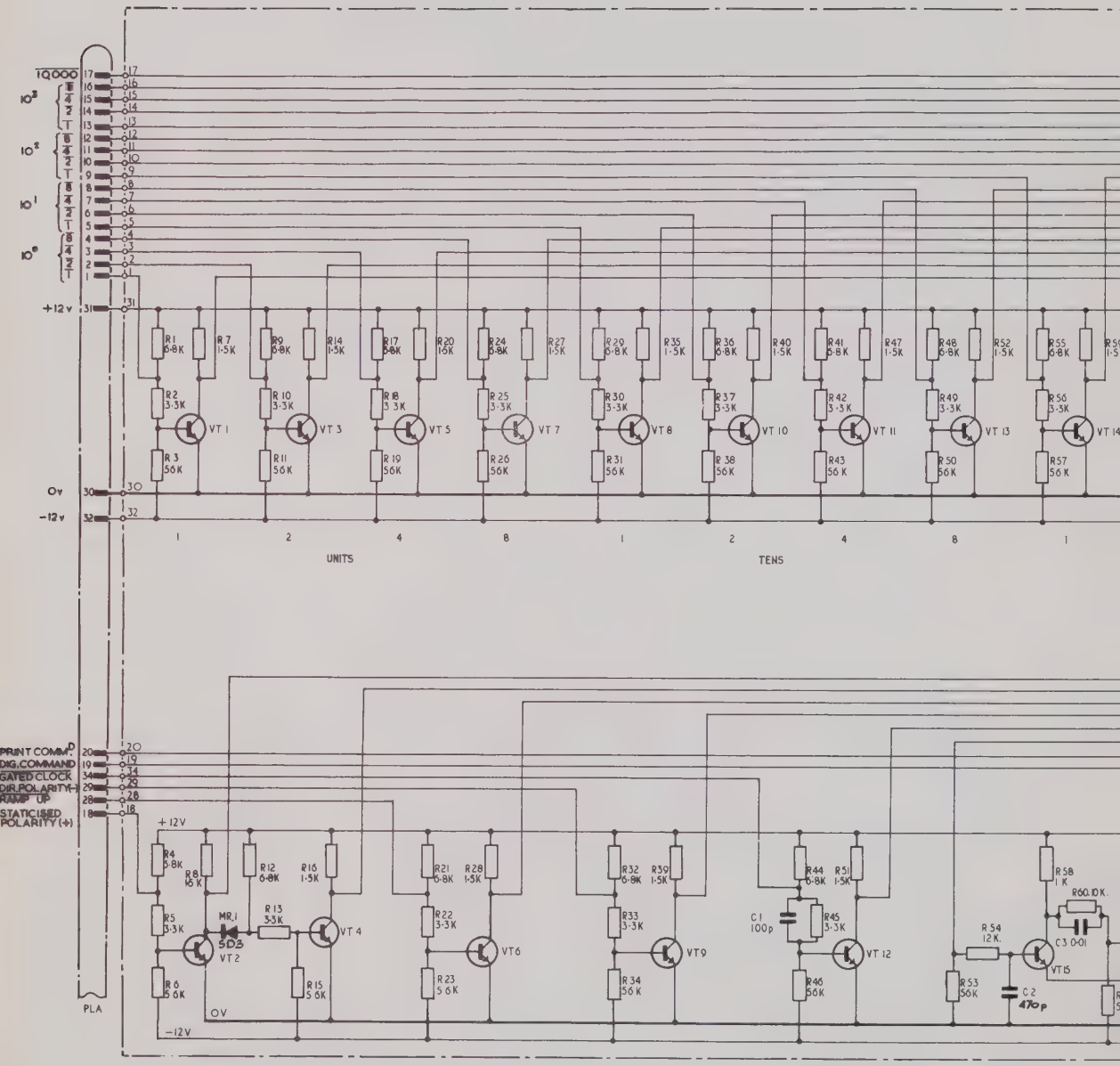
A HIGH, signifying binary 1, applied to SKA/m, switches on VT8 and the LOW on VT8 collector switches off VT10. The $\overline{1}$ and 1 lines in the diode decode network are thus LOW and HIGH respectively. Similarly, the $\overline{2}$ and 2 lines are LOW and HIGH respectively when a binary 2 input switches on VT4.

The $\overline{4}$ and 4 lines are driven from transistors VT9 and VT11. VT3 and VT5 with diodes MR4 and MR5 provide protection should no binary inputs be present at SKA. Assuming that range 4 is called, the HIGH at SKA/p switches on VT3 and consequently VT5. MR4 is reverse biased by the LOW from VT5 collector but MR5 conducts applying a HIGH to VT9 base. The $\overline{4}$ and 4 lines are therefore LOW and HIGH respectively. When range 4 is not called and SKA/p is a LOW, VT3 still conducts but its emitter will now be LOW. VT5 base is still biased positively and the transistor remains on. Since both MR4 and MR5 anodes are now LOW, VT9 is cut off and the $\overline{4}$ and 4 lines revert to HIGH and LOW respectively.

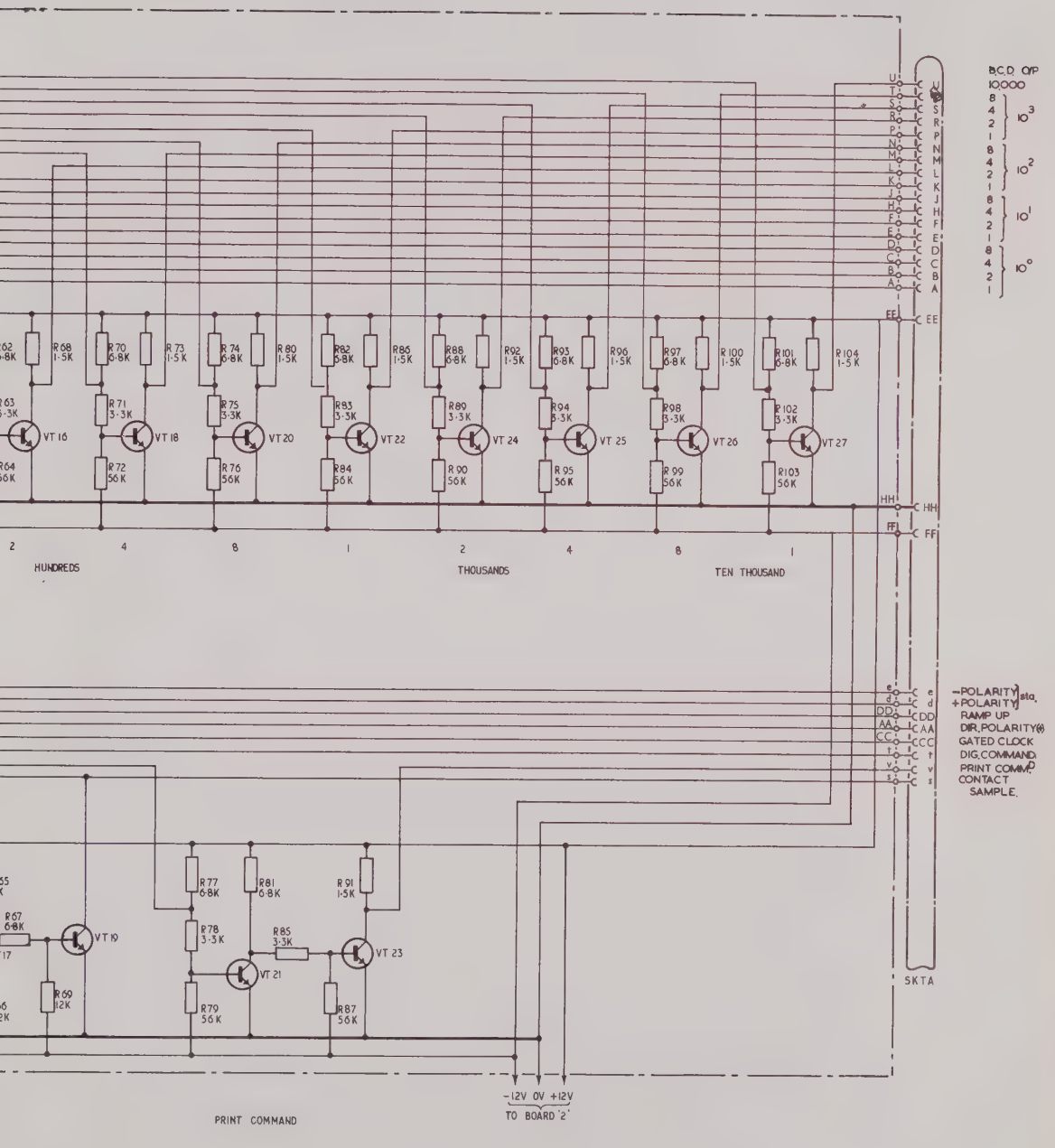
Suppose, now, that no inputs are applied to any of the BCD range command sockets - a condition which could occur with a failure in the external drive circuitry. VT3 base is floating and the transistor does not conduct. Its emitter, therefore, will be at -12 volts cutting off VT5. MR5 is reverse biased but the HIGH from VT5 collector is passed via MR4 and VT9 base and the $\overline{4}$ and 4 lines are LOW and HIGH respectively. Range 4 [200V F.S.D.] is called under these conditions ensuring that the voltmeter is switched to a range where damage is unlikely.

BCD INPUT	HIGH LINES	AND GATE OPEN	TRANSISTORS SWITCHED ON	RANGE CALLED	SKA pins HIGH
All lines open Circuit	$\overline{1}$ $\overline{2}$ $\overline{4}$	MR31 - 34	VT18, VT14 VT16	4 [100V]	j
0	$\overline{1}$ $\overline{2}$ $\overline{4}$	MR8 - 11	VT12, VT14 VT16, VT19	0 [10mV]	NONE
1	1 $\overline{2}$ $\overline{4}$	MR12 - 15	VT13, VT16 VT19	1 [100mV]	f
2	$\overline{1}$ 2 $\overline{4}$	MR20 - 23	VT15, VT14 VT19	2 [1V]	h
3	1 2 $\overline{4}$	MR27 - 30	VT17, VT19	3 [10V]	f, h
4	$\overline{1}$ $\overline{2}$ 4	MR31 - 34	VT18, VT14 VT16,	4 [100V]	j
5	1 $\overline{2}$ 4	MR38 - 41	VT20, VT16	5 [1000V]	f, j
6	1 2 4	NONE	VT14, VT16 VT19	NONE	NONE
7	1 2 4	MR42 - 45	VT21	AUTO	f, h, j

Table 3.7 · BCD–Decimal Decode



TRANSISTORS VT1 TO VT27 INC. D2039/D1501



EX3054 Fan Out Unit

Board No. 1

D30547000

Range Selection

As an example, suppose that SKA/m and n are supplied with a HIGH [i.e. range 3 is commanded] and that the REMOTE push-button SJ2 is depressed. The 1, 2 and $\overline{4}$ lines in the decode network will be HIGH with all others LOW. An examination of the potentials on the cathodes of the decode matrix diodes reveals that only those connected to VT17 base are all HIGH. VT17 therefore conducts, shorting PLA pin 24 to 0 volts and calling range 3 [10V] relays in the voltmeter.

VT14, VT16 and VT19 bases are connected to diode AND gates whose output is HIGH when all inputs are HIGH. In this example MR18 and MR25 cathodes are both held at 0 volts by VT17, VT14 and VT16 are therefore cut off. Since MR36 is not conducting, the bias on VT19 base is determined by the resistors R58, R59 and R60 and is such that VT19 conducts. SKA/f and h are thus HIGH, while SKA/j is LOW, representing a binary 3.

If the AC or DC switches on the voltmeter front panel are depressed, plug PLA pin 33 is clamped to 0V. All the decimal drive transistors are inhibited and no ranges can be called remotely.

Auto Ranging

When the auto range board EX3055 is fitted, range commands are applied both to LM1604 PLC to energise the appropriate d.c. range relay and also to EX3052 PLA pins 21-25. The decimal input from the EX3055 is thus decoded into a B.C.D. output at SKA/f, h and j.

Table 3.8 EX3054 SKA Connections

PIN NO.	FUNCTION	REMARKS
A	1	Staticised BCD outputs presented in parallel with the displayed reading. A HIGH is the active state.
B	2	
C	4	
D	8	
	Units [10_0]	
E	1	
F	2	
H	4	
J	8	
	Tens [10_1]	
K	1	
L	2	
M	4	
N	8	
	Hundreds [10_2]	
P	1	
R	2	
S	4	
T	8	
	Thousands [10^3]	
U	1 Tenthousand [1_4]	
d	+ve Polarity	Staticised polarity information. A HIGH signifies a positive voltmeter input signal. Refer to 'Staticised Polarity'.
e	-ve Polarity	Staticised polarity information. A HIGH signifies a negative voltmeter input signal. Refer to 'Staticised Polarity'.
f	1	BCD indication of the range which has been remotely selected. The active state is HIGH. Refer to 'BCD Range Commands'.
h	2 Range Output	
j	4	
k	Sub Unit Output	A HIGH signifies that remote a.c. operation has been commanded.

PIN NO.	FUNCTION	REMARKS
m n p	1 2 4 Range Command	D.C. or a.c. ranges can be commanded by applying the appropriate BCD inputs. The active state is HIGH. Refer to 'BCD' Range Commands' et seq.
r	Sub Unit Command	A HIGH enables a.c. range relays in EX1605 to be commanded via SKA pins m, n and p providing that the REMOTE push-button on LM1604 is pressed. Refer to 'A.C. Sub Unit Command'.
s	Contact Sample	The voltmeter can be commanded to staticise by applying a LOW. Refer to 'Contact Sample'.
t	Digitise Command	The voltmeter can be commanded to staticise by applying a positive pulse. Refer to 'Digitise Command'
v	Print Command	A HIGH indicates that the measurement of the voltmeter input is complete. This applies only on manual or autorange operation. Refer to 'EARTHY LOGIC - Print Command Signals.'
AA	Direct Polarity	An indication of input signal polarity is available >15μs after the end of Ramp Up. Refer to Direct Polarity.
CC	Gated Clock	Positive-going gated clock pulses. Refer to 'Gated Clock".
DD	Ramp Up	A HIGH indicates that Ramp Up is in progress Refer to 'Ramp Up'.
EE	+12V	
FF	-12V	
HH	0V	

Voltage and Current Levels

All Outputs: Common emitter stages with 1.5kΩ load to the +12V supply, capable of sinking a further 10mA load current.

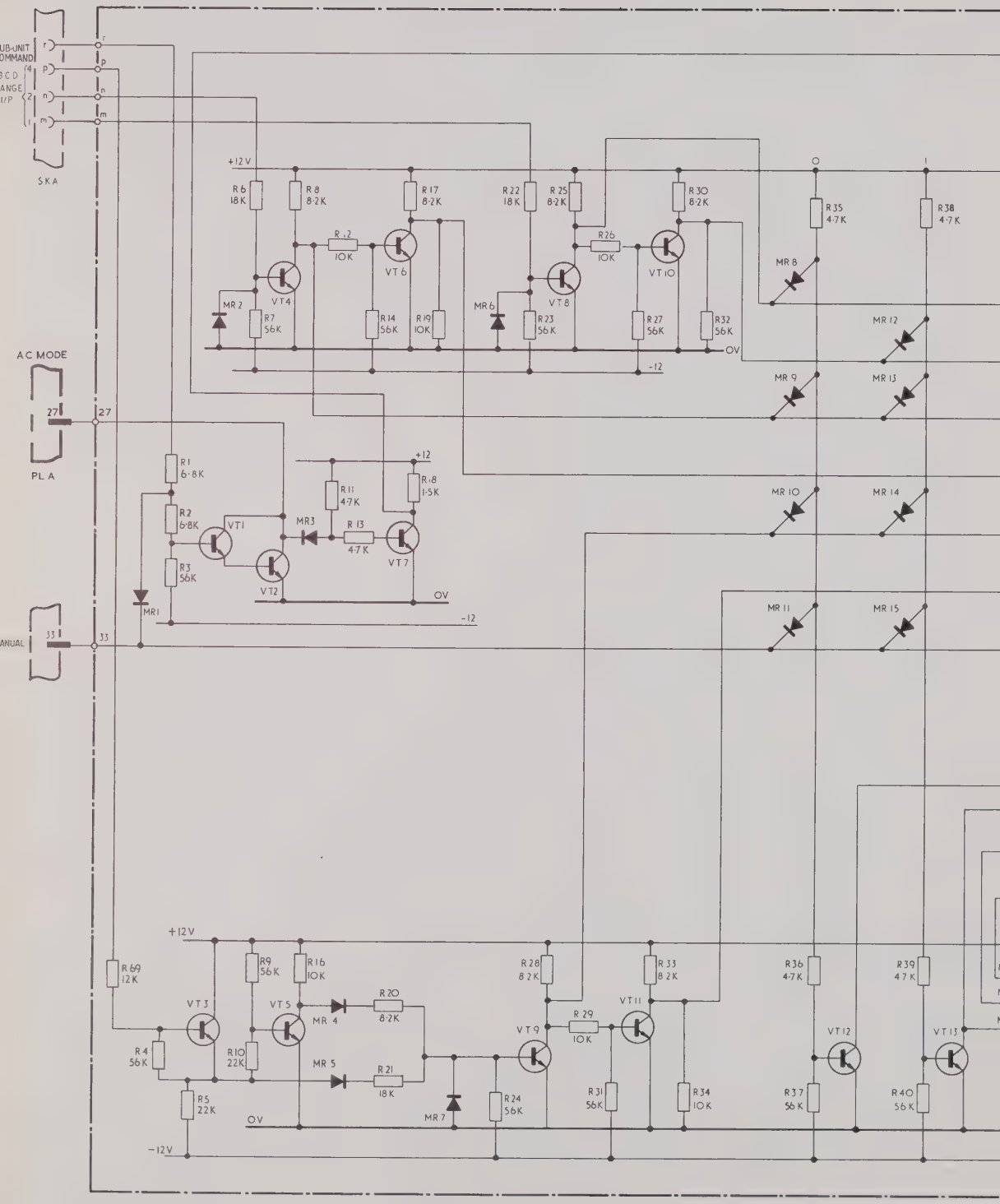
Digitise Command Input: Pulse amplitude >+8 volts and < +14 volts
Duration >10μs
Input impedance >10kΩ

The EX3054 will not deliver an input to LM1604 under either of the following conditions:- a] Pulse amplitude <+2V
b] Duration <1μs with a duty cycle not greater than 0.1

Other Inputs:

HIGH is >+9 volts and <+15 volts
Input current <1mA

LOW is >0 volts and <+1 volt
Input current <0.5mA



TRANSISTORS VT1 TO VT21 INC D2039/D1501
DIODES MR1 TO MR45 INC SD3, PLA & SKTA
ARE LOCATED ON P.C.B. 3054900I

02 15·12·69

EX3054 Fan Out Unit

Board No. 2

D 30547000

NEGATIVE LOGIC FAN OUT UNIT EX3052

Introduction

Similar in construction to the positive logic Fan Out Unit, the EX3052 consists of two printed circuit boards, the first of which provides buffering stages between voltmeter and external equipment, and the second range decoding and certain other logic functions. The unit is designed specifically for use with the Solartron Compact Logger Series 2.

Board 1

Counter Outputs

Staticised outputs from the LM1604 display counter are applied to plug PLA/1-17 and associated transistors VT1 - VT34. Outputs at socket SKA/A-U will be LOW [-12] when the relevant bit has been stored by the counter.

The optional link between VT34 collector and MR19 is provided should it be required to limit the maximum indication from SKA/A-U to 9999. If the display registers greater than this, then the 10 000 stage VT33, VT34 will have been operated with VT34 switched off. With the link connected, zener diode MR19 will hold VT35 conducting and approximately +3 volts will be connected from the anode of MR18 to the anodes of diodes MR1 - MR16 thereby cutting off transistors VT2, 4, 6 etc., and indicating 9999 at SKA/A-U.

Print Command

VT45, 46 and 47 amplify and invert the print command signal from the voltmeter providing a LOW at SKA/v.

Digitise Command

Staticisation is commanded by applying a negative pulse to SKA/t to fire the Schmitt Trigger VT48, VT49. For the duration of the input pulse, VT50 is switched off and VT51 on, supplying the required 0 volts to PLA/19.

At the end of the next measurement cycle following the application of the digitise command pulse, the display will be up dated by the staticise pulse. [Note that both the 25/s and MANUAL push-buttons must be released before this facility is available].

Contact Sample

If a digitise command pulse is not available, staticisation can be commanded by shorting SKA/s to SKA/HH which will again apply the required 0 volts to PLA/19. This can be done, for example, by a relay contact.

Gated Clock

The gated clock pulses, [1MHz during ramp up, 2MHz during ramp down] are applied to PLA/34. After inversion both by VT43 and VT44, these are connected to SKA/CC. The output is thus positive-going pulses but with respect to -12 volts.

Direct Polarity

A positive polarity voltmeter input will give a permanent LOW at PLA/29. VT41 and VT42 will conduct to supply 0 volts to SKA/AA. [Refer to figure 3.20]. A negative polarity voltmeter input will result in the direct polarity waveform of figure 3.22 being applied to VT41 base. This same waveform but with a -12 volt base-line will appear at SKA/AA. Direct polarity information is available at the end of the ramp up period.

Staticised Polarity

A positive polarity voltmeter input will cause a HIGH to be applied to PLA/18 after the staticise pulse has occurred.

VT36 will switch off and VT37 on to give outputs of 0 volts at SKA/d and, since VT38 is also cut off, -12 volts at SKA/e. If a negative polarity voltage is being measured, a LOW applied to VT36 base will cause the potentials at SKA/d and e to alter to -12 volts and 0 volts respectively. Since these are staticised outputs, polarity decisions are not available until the beginning of the drift correct period. [Refer to figure 3.25].

Ramp Up

The $\overline{\text{Ramp Up}}$ output from the slave ramp up bistable is applied to PLA/28. VT39 and 40 both invert this signal resulting in an output at SKA/DD, which is at -12 volts only during the ramp up period.

Board 2

A.C. Sub Unit Command

Provided that the REMOTE push-button SJ2 is depressed, a -12 volt command applied to SKA/r will switch on VT1 and VT2. VT2 collector is connected to +12 volts via R2 on LM1604 board 9 and the consequent output at PLA/27 is 0 volts, which permits the a.c. range relays to be selected. [Refer to 'Range Switching and Mode Selection']. VT3 is switched on via MR2 and VT4 is cut off off applying -12 volts to SKA/k.

If the REMOTE push-button is not selected, PLA/33 is held at 0 volts. Thus, when SKA/r is at -12 volts, MR1 conducts and VT1 base remains positive and hence a.c. range relays cannot be selected remotely.

If no sub-unit command is applied to SKA/r, VT1 will remain cut off allowing the d.c. range relays to be energised as required.

B.C.D. Range Commands

Any a.c. or d.c. range can be remotely commanded by applying a BCD command to SKA/m, n and p. The ranging code is as in table 3.9.

RANGE	DECIMAL DRIVE	B.C.D. INPUT		
		SKA/m	n	p
10mV	0	HIGH	HIGH	LOW
100mV	1	LOW	LOW	HIGH
1V	2	HIGH	LOW	HIGH
10V	3	LOW	HIGH	HIGH
100V	4	HIGH	HIGH	HIGH
1000V	5	LOW	HIGH	LOW
Autorange	7	LOW	LOW	LOW

(HIGH = 0 volts; LOW = -12 volts)

Table 3.9 Ranging Code

The BCD inputs are decoded on to seven lines. Diode/resistor NAND gates detect 0-5 or 7 and drive amplifiers whose outputs energise the a.c. or d.c. range relays as required.

A binary 7 range input, energises none of the range relays but commands the Auto-range mode in which, if the EX3055 Auto-range board is fitted, d.c. range selection is automatic.

In addition a Special Auto-range Command facility is available which not only selects the auto-range mode but inhibits the BCD/decimal decoding and drive circuits allowing an indication of the range selected to appear on SKA/m, n and p.

Binary to Decimal Decode

With reference to table 3.9, a BCD input is applied to SKA/m, n and p to select the required range. Assuming that range 3 is commanded, then -12V must be applied to socket m, with 0 volts on n and p. VT26 will therefore conduct, cutting off VT27. VT28 and VT30 will both be cut off and VT29 and VT31 will conduct. Assuming also that manual range selection is not required, then the REMOTE push-button SJ on the LM1604 will be depressed. This removes an inhibiting 0 volts from PLA/33 and allows normal remote range selection to take place.

Hence, by examining the outputs from the collectors of transistors VT26 - VT31, the conditions at the four inputs of each diode/resistor NAND gate can be determined. In this particular example, only the anodes of diodes MR32 - 34 are returned to -12 volts and consequently cut off. Since, also, MR31 anode is floating, the NAND gate composed of these four diodes and R77 is open and, from a consideration of the values of R30, R31 and R77, VT15 and 16 will be switched on to energise range 3 range relay in the voltmeter. All other diode/resistor gates will, by examination, be seen to be closed by the 0 volts applied to at least one of the diode anodes. Hence all other range relay drive transistors will remain cut off.

Should manual range selection be required, switch SJ on the LM1604 will not be depressed and all NAND gates will be inhibited by the 0 volts applied to diodes MR13, 20, 27, 31, 35, 39 and 43. No remote range selection via the fan out unit will then be possible.

Protection Against Range Command Failure

Should no range commands be applied to SKA/m, n and p, transistors VT26, 28 and 30 will conduct, cutting off VT27, 29 and 31. Under these conditions, MR36 - MR38 will be cut off and range 4 [200V F.S.D.] will be selected.

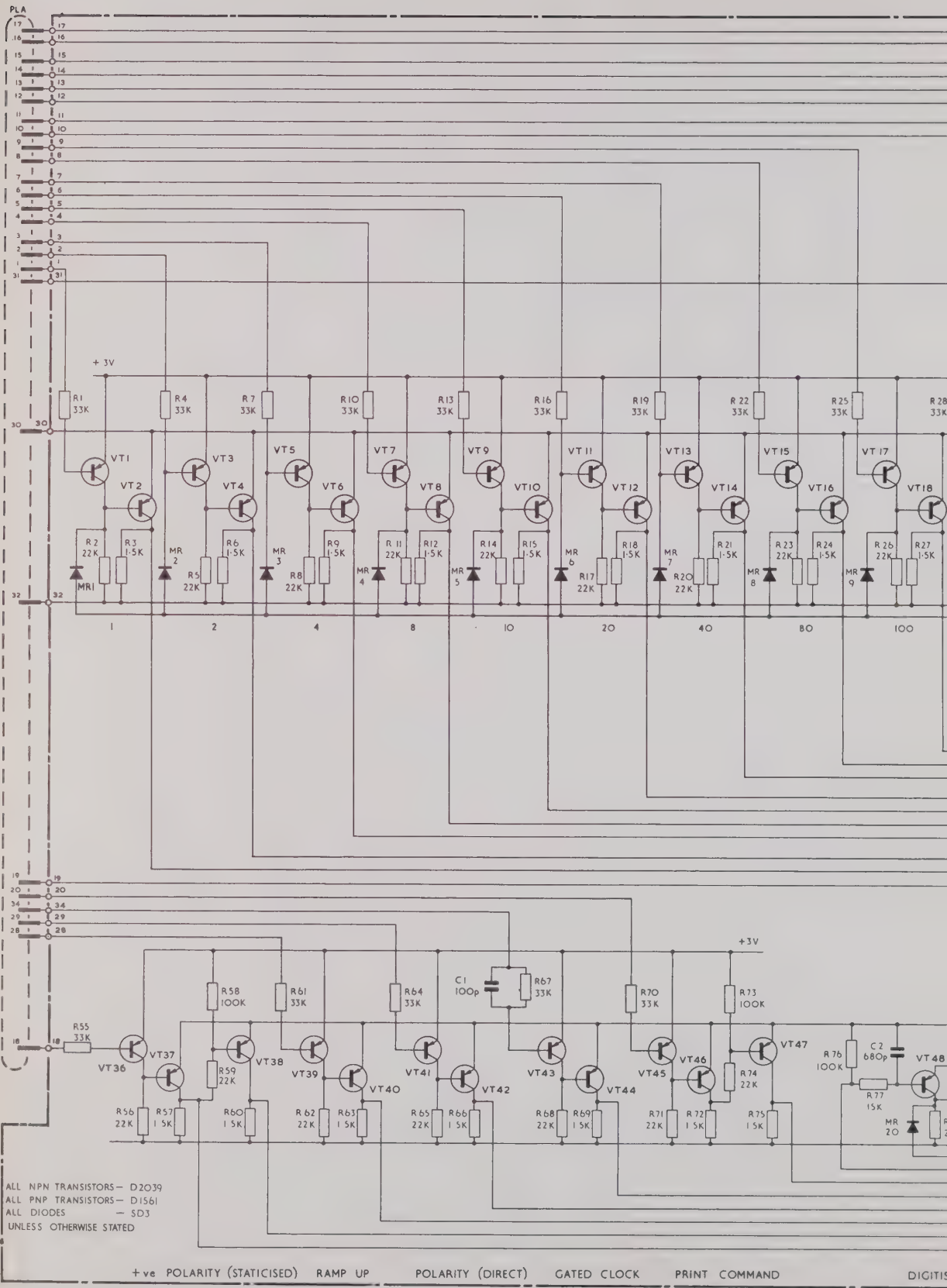
B.C.D. Range Outputs

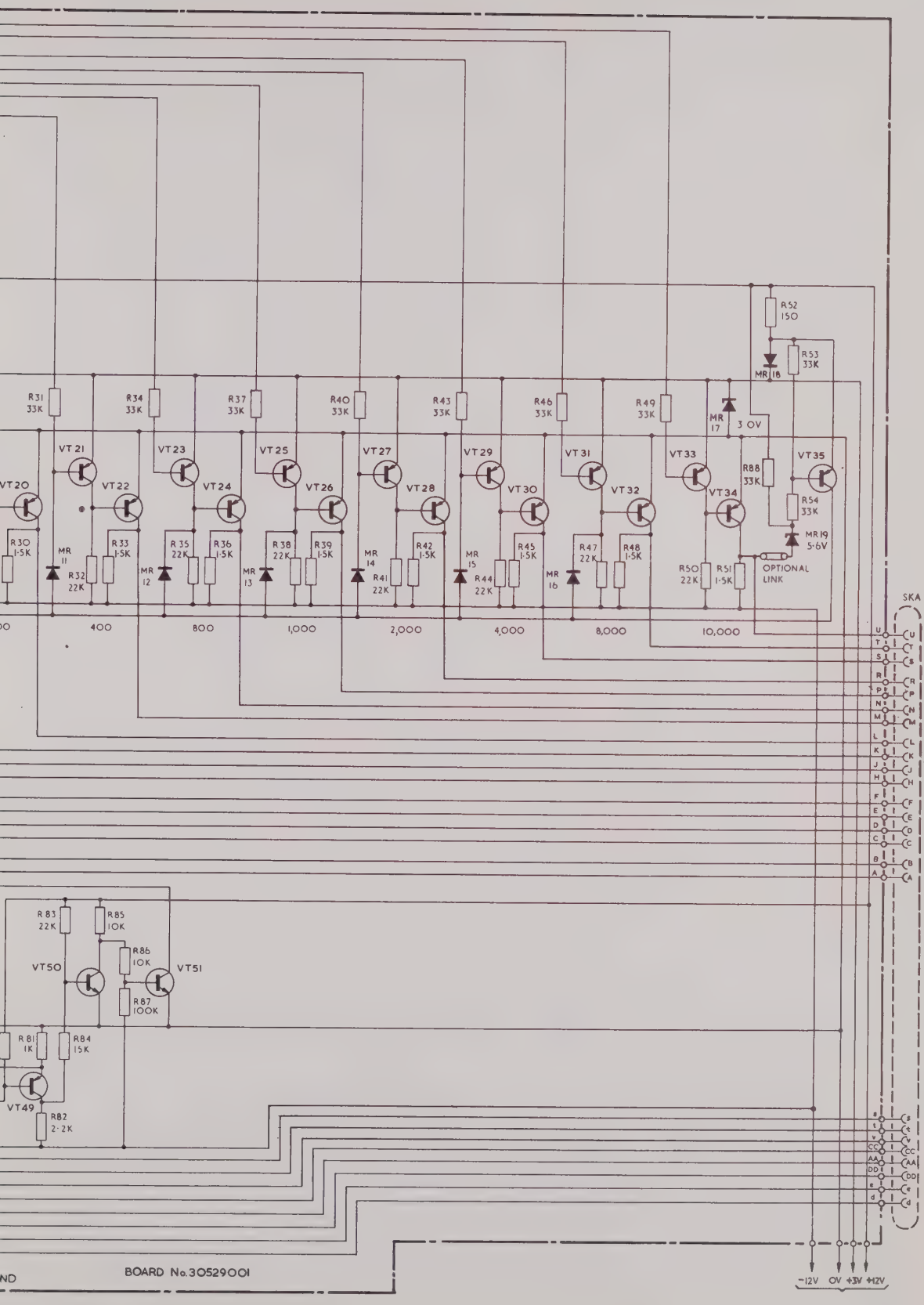
The decimal range commands which energise the range relays are encoded back into BCD form by three diode OR gates and passed via amplifiers to SKA/f, h and j to give an indication of the range selected.

The ranging code is illustrated in table 3.10 overleaf

A 0 volts range command applied to the appropriate pin on PLA will be detected by at least one of the OR gate diodes MR3 - MR9. If, for example, range 3 is commanded, then both MR3 and MR7 will conduct and VT9 and VT13 will switch on. VT10 and VT14 will cut off applying -12 volts to SKA/f and h [binary 3]

In a similar way, other decimal range commands are encoded giving the BCD outputs designated in table 3.10


PLA
+3V
R1 33K
R4 33K
R7 33K
R10 33K
R13 33K
R16 33K
R19 33K
R22 33K
R25 33K
R28 33K
VT1
VT2
VT3
VT4
VT5
VT6
VT7
VT8
VT9
VT10
VT11
VT12
VT13
VT14
VT15
VT16
VT17
VT18
R2 22K
R3 1·5K
R5 22K
R6 1·5K
R8 22K
R9 1·5K
R11 22K
R12 1·5K
R14 22K
R15 1·5K
R17 22K
R18 1·5K
R20 22K
R21 1·5K
R23 22K
R24 1·5K
R26 22K
R27 1·5K
MR1
MR 2
MR 3
MR 4
MR 5
MR 6
MR 7
MR 8
MR 9
1
2
4
8
10
20
40
80
100
+3V
R55 33K
R58 100K
R61 33K
R64 33K
C1 100p
R67 33K
R70 33K
R73 100K
VT36
VT37
VT38
VT39
VT40
VT41
VT42
VT43
VT44
VT45
VT46
VT47
R56 22K
R57 1·5K
R59 22K
R60 1·5K
R62 22K
R63 1·5K
R65 22K
R66 1·5K
R68 22K
R69 1·5K
R71 22K
R72 1·5K
R74 22K
R75 1·5K
R76 100K
C2 680p
R77 15K
VT48
MR 20
ALL NPN TRANSISTORS – D2039
ALL PNP TRANSISTORS – D1561
ALL DIODES – SD3
UNLESS OTHERWISE STATED
+ve POLARITY (STATICISED) RAMP UP
POLARITY (DIRECT) GATED CLOCK
PRINT COMMAND
DIGITIS



EX3052 Fan Out Unit

D 30527000 SHT. 1

Board No. 1

RANGE	DECIMAL DRIVE	SKA	f	h	j
		BCD	1	2	4
10mV	0		HIGH	HIGH	LOW
100mV	1		LOW	LOW	HIGH
1V	2		HIGH	LOW	HIGH
10V	3		LOW	HIGH	HIGH
100V	4		HIGH	HIGH	HIGH
1000V	5		LOW	HIGH	LOW

(HIGH = 0 volts LOW = -12 volts

Table 3.10 Range Output Code

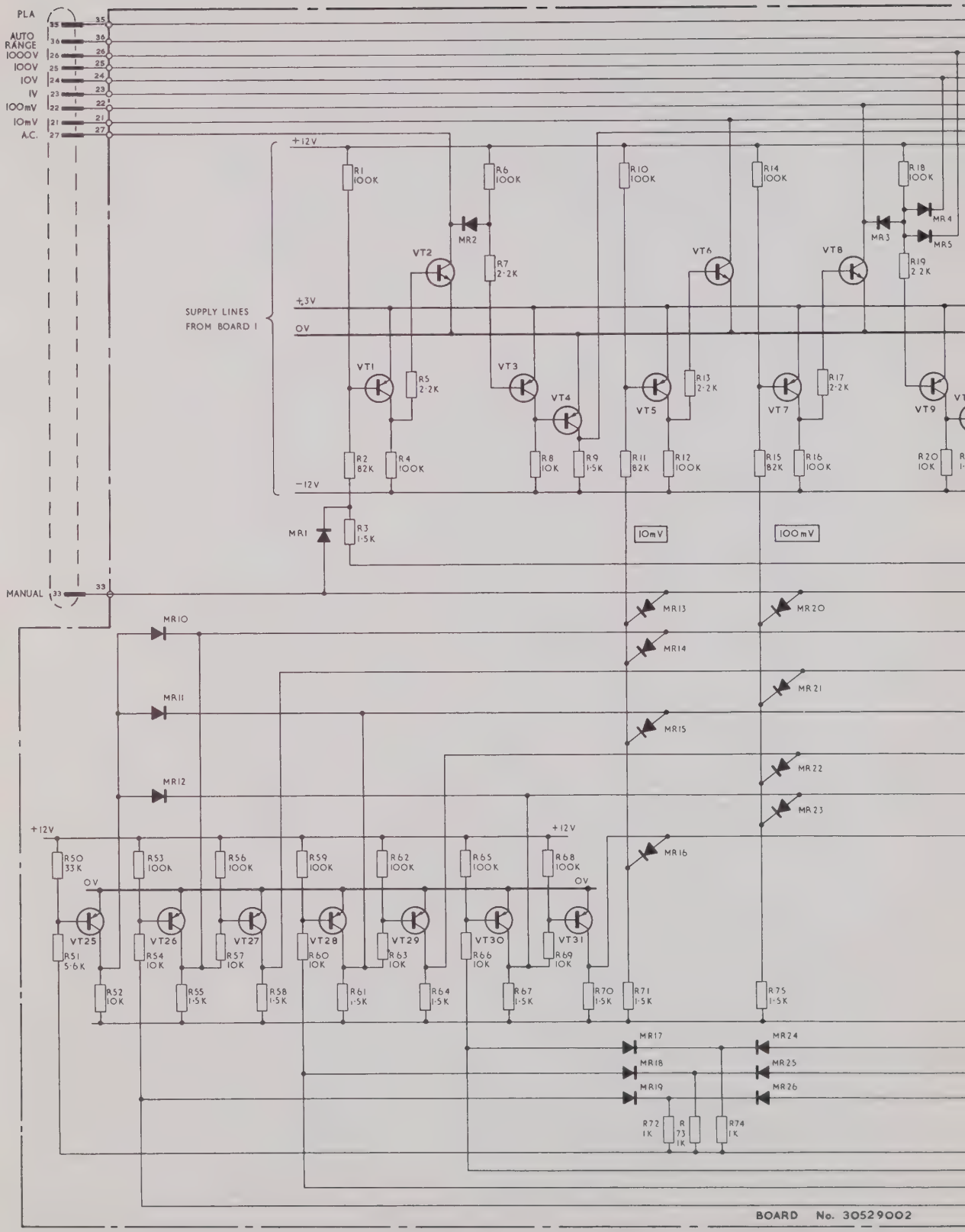
Special Autorange Command

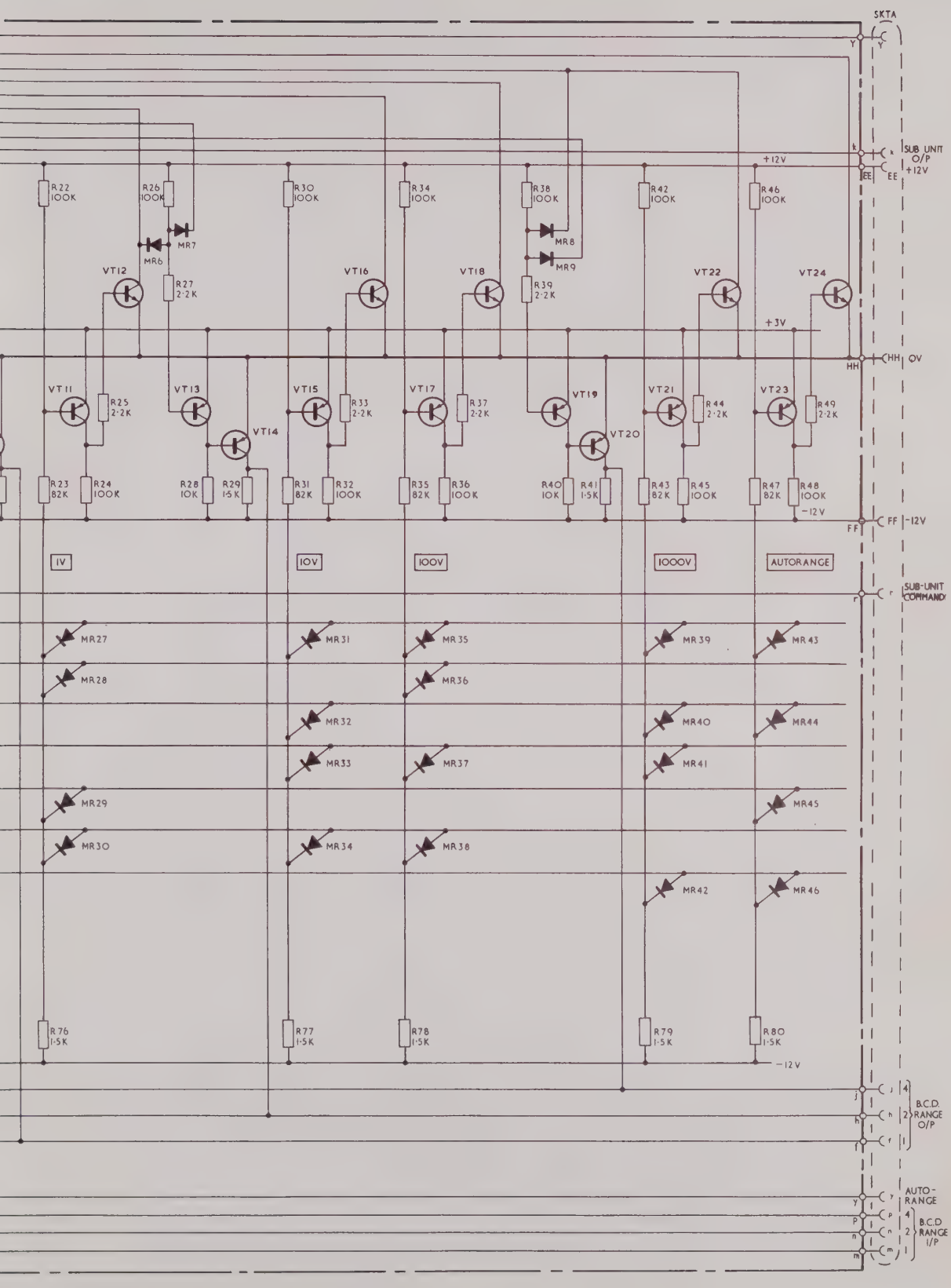
When a special auto-range command [-12 volts] is applied to SKA/y transistor VT25 switches on and holds the collectors of VT26, VT28 and VT30 at less than one volt via diodes MR10, 11 and 12 respectively. In this condition [equivalent to a binary 7 input] VT23 and VT24 are switched on and an auto-range command is issued via PLA/36.

As the auto-range board selects the various d.c. ranges, the information presented to PLA pins 21 - 25 is decoded by the OR gates and applied in BCD form to SKA/f, h and j. However, in this mode of operation the Compact Logger Series 2 requires a BCD input from SKA/m, n and p. Since SKA/y is maintained at -12 volts by the Special Auto-range Command, the gating network MR17 - 19, MR24 - 26 is open and the BCD range indications are passed to these sockets. When SKA/y reverts to 0 volts, the gating network is inhibited with SKA/m, n and p effectively isolated from f, h and j.

Table 3.11 EX3052 SKA Connections

PIN NO.	FUNCTION	REMARKS
A B C D	$\overline{1}$ $\overline{2}$ $\overline{4}$ $\overline{8}$ — Units [10_0]	Staticised BCD outputs presented in parallel with the displayed reading. The active state is LOW.
E F H J	$\overline{1}$ $\overline{2}$ $\overline{4}$ $\overline{8}$ — Tens [10_1]	
K L M N	$\overline{1}$ $\overline{2}$ $\overline{4}$ $\overline{8}$ — Hundreds [10_2]	
P R S T	$\overline{1}$ $\overline{2}$ $\overline{4}$ $\overline{8}$ — Thousands [10_3]	
U	$\overline{1}$ — Tenthousand [10_4]	
d	-ve Polarity	Staticised polarity information. LOW signifies a negative voltmeter input signal. Refer to 'Staticised Polarity'.
e	+ve Polarity	Staticised polarity information. LOW signifies a positive voltmeter input signal. Refer to 'Staticised Polarity'.
f h j	$\overline{1}$ $\overline{2}$ $\overline{4}$ — Range Output	BCD indication of the range which has been remotely selected. The active state is LOW. Refer to 'BCD Range Outputs'.
k	Sub Unit Output	A LOW signifies that remote a.c. operation has been commanded.
m n p	$\overline{1}$ $\overline{2}$ $\overline{4}$ — Range Command	D.C. or a.c. ranges can be commanded by applying the appropriate BCD inputs. The active state is LOW. Refer to 'BCD Range Commands'. et seq.
r	Sub Unit Command	A LOW enables a.c. range relays in EX1605 to be commanded via SKA pins m, n and p providing that the REMOTE push-button on LM1604 is pressed. Refer to 'A.C. Sub Unit Command'.
s	Contact Sample	The voltmeter can be commanded to staticise by applying a HIGH. Refer to 'Contact Sample'.
t	Digitise Command	The voltmeter can be commanded to staticise by applying a negative oulse. Refer to 'Digitise Command'.


PLA
AUTO RANGE
1000V
100V
10V
1V
100mV
10mV
A.C.
MANUAL
SUPPLY LINES FROM BOARD 1
+12V
+3V
0V
-12V
R1 100K
R6 100K
R10 100K
R14 100K
R18 100K
R19 2·2K
R2 82K
R4 100K
R5 2·2K
R7 2·2K
R8 10K
R9 1·5K
R11 82K
R12 100K
R13 2·2K
R15 82K
R16 100K
R17 2·2K
R20 10K
R3 1·5K
MR1
MR2
MR3
MR4
MR5
VT1
VT2
VT3
VT4
VT5
VT6
VT7
VT8
VT9
10mV
100mV
MR10
MR11
MR12
MR13
MR14
MR15
MR16
MR17
MR18
MR19
MR20
MR21
MR22
MR23
MR24
MR25
MR26
R50 33K
R53 100K
R56 100K
R59 100K
R62 100K
R65 100K
R68 100K
R51 5·6K
R52 10K
R54 10K
R55 1·5K
R57 10K
R58 1·5K
R60 10K
R61 1·5K
R63 10K
R64 1·5K
R66 10K
R67 1·5K
R69 10K
R70 1·5K
R71 1·5K
R75 1·5K
R72 1K
R 73 1K
R74 1K
VT25
VT26
VT27
VT28
VT29
VT30
VT31
BOARD No. 30529002



EX3052 Fan Out Unit

D 30527000

Board No. 2

PIN NO.	FUNCTION	REMARKS
v	Print Command	A LOW indicates that the measurement of the voltmeter input is complete. This applies only on manual or autorange operation. Refer to 'EARTHY LOGIC - Print Command Signals.
y	Autorange	A LOW commands autorange operation. Refer to 'Special Autorange Command'.
AA	Direct Polarity	An indication of input signal polarity is available >15μs after the end of Ramp Up. Refer to 'Direct Polarity'.
CC	Gated Clock	Positive-going gated clock pulses. Refer to 'Gated Clock'.
DD	Ramp Up	A LOW indicates that Ramp Up is in progress, Refer to 'Ramp Up'.
EE	+12V	
FF	-12V	
HH	0V	

Voltage and Current Levels

All Outputs: Common emitter stages with 1.5kΩ load to the -12V supply, capable of sinking a further 5mA load current.

Digitise Command Input:

Pulse amplitude	-12V ±3V
Duration	>10μs
Input Impedance	>10kΩ

The EX3052 will not deliver an input pulse to LM1604 under either of the following conditions:

a] Pulse amplitude <2V
b] Duration <1μs with a duty cycle not greater than 0.1

Other Inputs:

HIGH is -0.5V ±0.5V
Input current <0.5mA
LOW is -12V ±3V
Input current <2mA

SERVICING

INTRODUCTION

The inherent reliability deriving from the use of Integrated Circuits, Silicon Semi-conductors and long life Cold Cathode Indicators eliminates the need for a regular maintenance procedure.

The following information is provided to assist in the location and rectification of faults and the replacement of defective items.

RECOMMENDED TOOLS

Large and small Pozidrive screwdriver
Flat bladed screwdriver with $\frac{1}{4}$" blade
Flat-bladed screwdriver with 1/8" blade
Set of open-ended BA spanners [Even sizes]
Pair of tweezers or long-nosed pliers

The above tools will enable all the servicing described in the following paragraphs to be carried out. Additionally - where components are to be removed from boards - it will be found convenient to use a soldering iron with some form of pump to remove excess solder and prevent damage to the copper track.

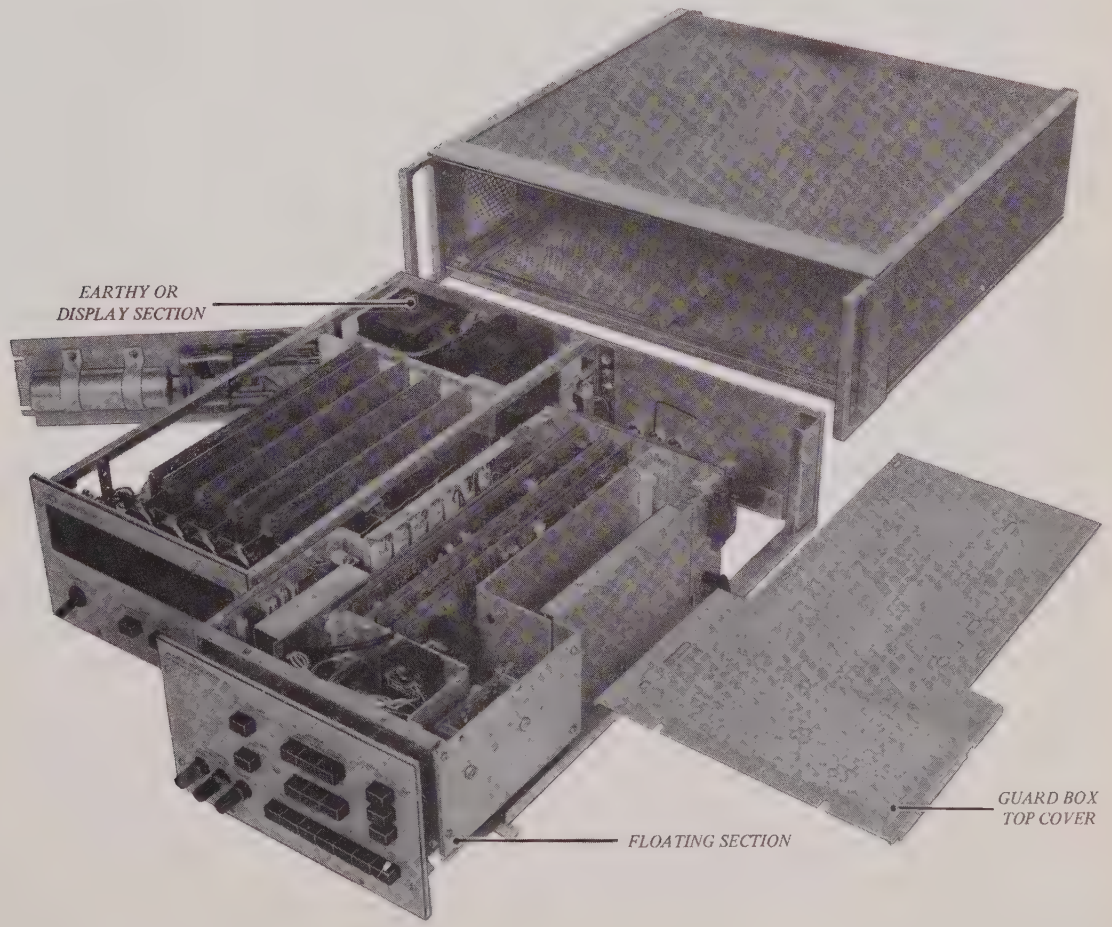


Figure 4.1 LM1604 Dismantled for Servicing

DISMANTLING INSTRUCTIONS

The voltmeter divides physically into two parts: the floating section and the display section - both being enclosed in a protective case. Before removing either sub unit, it is recommended that the mains input lead be removed to avoid the possibility of short circuiting any of the supplies.

Removal of the Floating Section

The floating section may be withdrawn from the voltmeter without first removing the instrument case.

After undoing the two securing screws at the bottom edge of the front panel below the INPUT LOW terminal and the 10V range push-button, the floating section may be withdrawn from the main unit by pulling firmly on one of the input terminals.

NOTE
Since it is intended that later versions of the LM1604 and LM1604/05 voltmeters will be supplied with a one-piece front panel, the floating and display sections will, in this event, not be separable unless this is first removed by undoing the nine Pozidrive screws from around the panel edge. The following dismantling instructions then still apply.

Figure 4.2 Removal of Floating Section

Access to Mother Board and Plug PLD

Remove the six screws around the edge of the perforated bottom plate and lift off to expose all connections to board 7 and plug PLD.

Removal of Boards 1, 3, 5 and 10

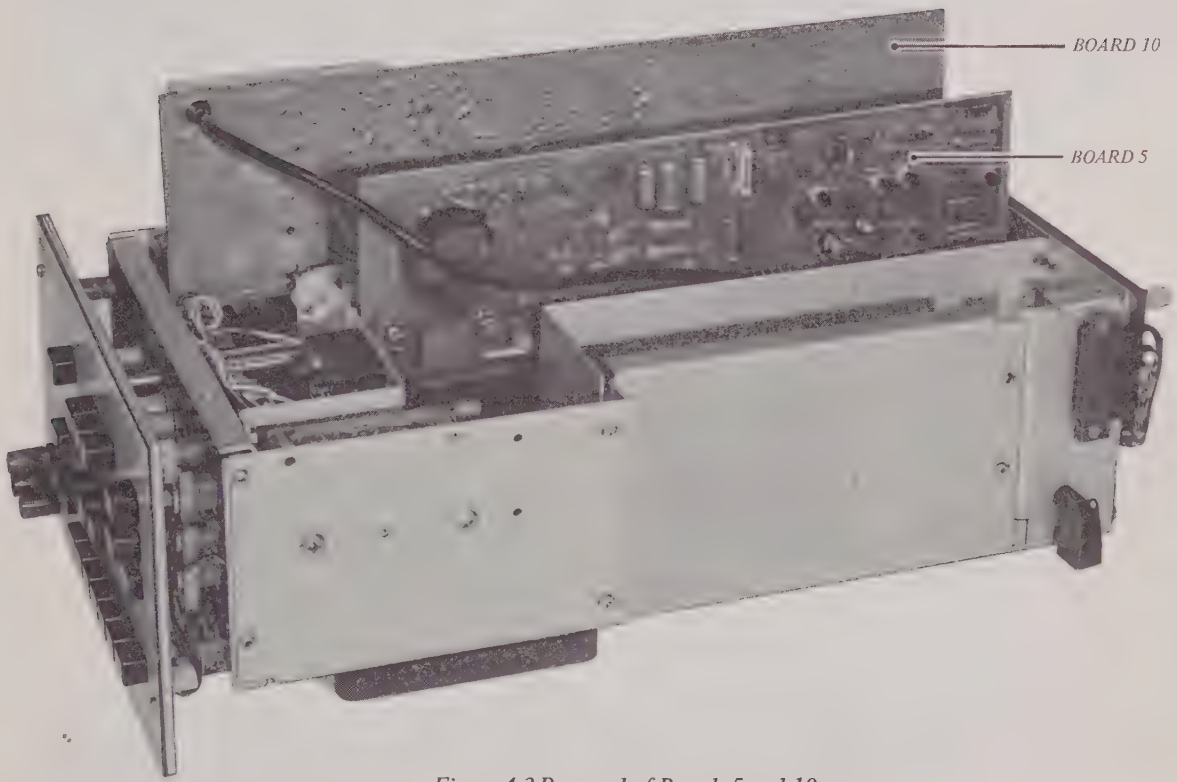


Figure 4.3 Removal of Boards 5 and 10

These boards are plug-in fittings retained in place by the perforated top cover which may be removed after undoing the six screws around its edge. Boards 1 and 3 may then be withdrawn by a direct upward pull.

Boards 5 and 10 are connected together by a screened lead and should preferably be removed together. After separating each board individually from its socket (approximately 0.5 inch) withdraw both boards simultaneously by a direct upward pull.

Once the boards have been removed the connnecting cable can be unplugged from the three terminal pins on board 5 by a firm direct pull with tweezers or long nosed pliers.

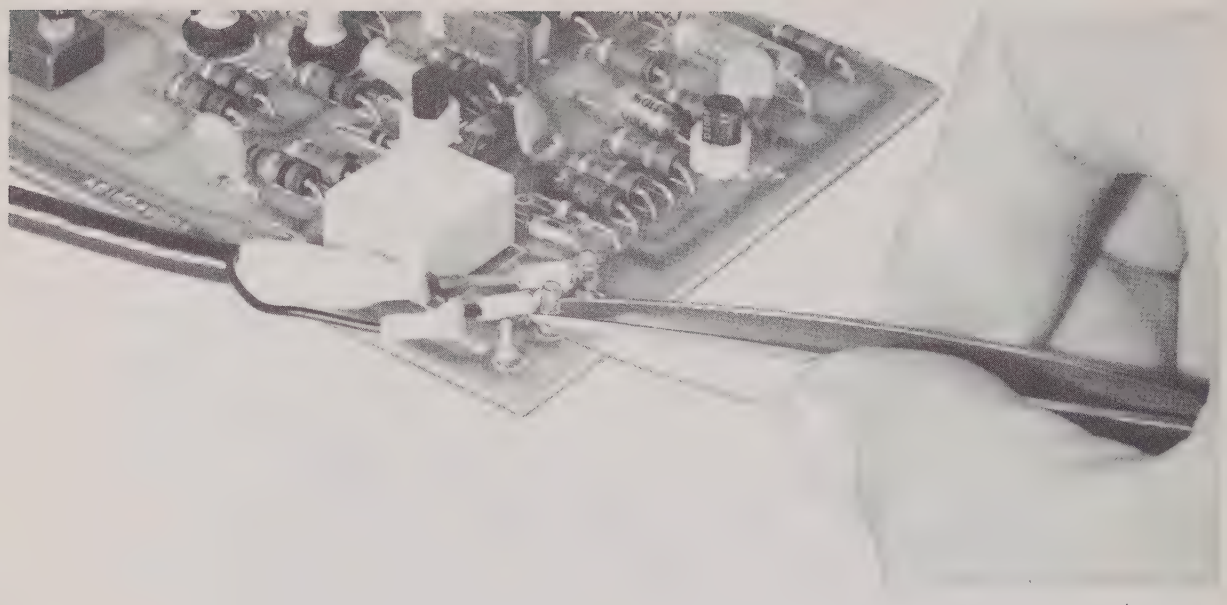


Figure 4.4 Removal of 'Disconnect' Terminals

Removal of Board 13

The screen box containing board 13 is mounted on board 10. Undo the five screws securing the cover to the box and remove the cover. This exposes the two compartments of the box, one of which contains the d.c. pre-amplifier and temperature compensation circuits, and the other board 13.

To gain access to the copper side of board 13, first prise of the plastic spacer and then remove the four securing screws situated underneath. The cover plate can now be removed exposing board 13. The board is retained in position by a single screw and can be raised for servicing after unsoldering the three wires connecting to the d.c. pre-amplifier.

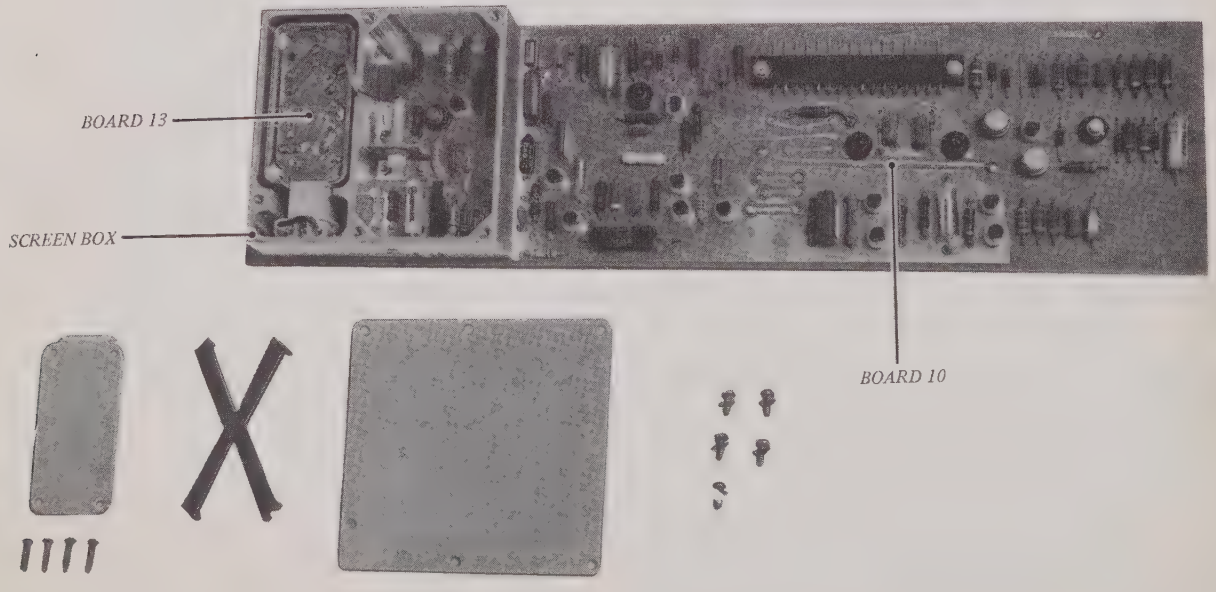


Figure 4.5 Access to Board 13

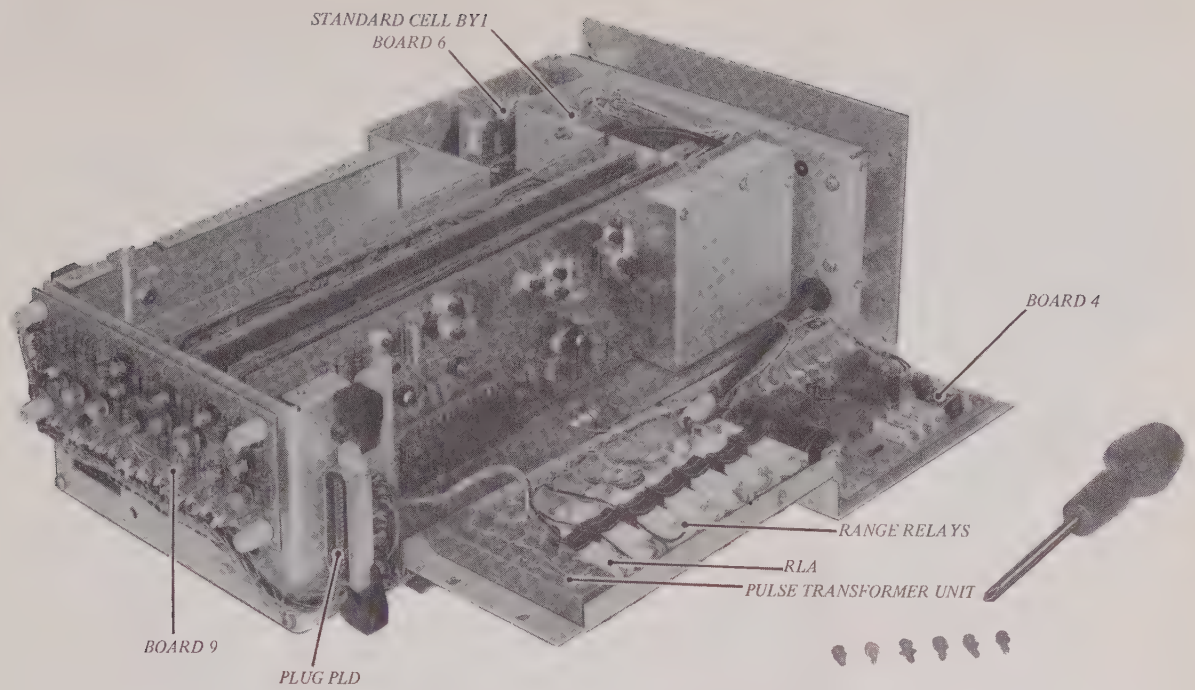


Figure 4.6 Component Location - Floating Section

Removal of Board 6

Viewed from the front panel, board 6 is mounted on three ½" pillars rivetted to the plate at the right front of the chassis. The plate is secured by six screws around its edge and must be removed to expose board 6. The board can be removed by undoing the three retaining screws and pulling off the seven 'disconnect' terminals.

Removal of Board 9

Board 9 is mounted on four PTFE insulators at the rear of the chassis and can be removed after undoing four self-tapping screws [one at each corner of the board] recessed in the insulators. All wired connections are of the 'disconnect' type.

Removal of Board 8

Board 8 is mounted on two PTFE insulators beneath the seven range relays on the left side chassis and is secured by two self-tapping screws. All wired connections are of the 'disconnect' type.

Removal of Board 4

Board 4 is mounted on four PTFE insulators on the inside face of the left side chassis. To remove the board unscrew the two screws on the left hand edge of the top cover and then the six screws around the edge of the side chassis which can then be laid flat to give access to the components. The foil side of board 4 is exposed by removing the four self tapping screws from around its edge. The board can then be hinged forward. Two easily accessible connections are permanently soldered while the remainder are of the 'disconnect' type.

Replacement of Range Relays

The seven range relays A-G are mounted in alphabetical order on the left side chassis with RLA nearest the rear. Relay coils can be replaced after the two securing screws have been removed [Board 8 must must be removed to expose the lower screw]. To change a reed, the side chassis must first be hinged out. The two black plastic retainers must then be prised off the requisite relay after which the white plastic insert on which the reed is mounted can be lifted clear.

Removal of Standard Cell

Firstly remove the top cover.
Mounted immediately behind the front panel switch wafers, the standard cell is retained in place by two screws. After removing the two nuts from these screws and unsoldering the + and - connections, the cell can be withdrawn.

Access to Range Switches and input Terminals

All connections are accessible immediately behind the front panel when the chassis is inverted.

Access to MODE Switches

All connections are accessible at the right of the chassis immediately behind the front panel.

Access to DC FILTERS and CAL Switches

The top cover must first be removed to expose connections to these switches and the calibration potentiometer.

Access to AC RESPONSE and μV ZERO Switches

Remove the bottom cover to expose all connections to these switches and the μV Zero potentiometer

Refitting of Boards

Adjacent to each socket on the mother board is a number indicating the plug-in board which locates in that position. In addition, the sockets are offset by different amounts so that, with the exception of 1 and 3, it is impossible to interchange boards.

Having found the correct location, the board should be inserted into the guides and pressed home firmly when it is certain that plug and socket are aligned. Alignment is achieved by lateral movement of the board between the guides if necessary.

When replacing boards 5 and 10, the connecting screened lead should be fitted in the channel adjacent to the standard cell BY1 and routed under the inverter transformer T1 on board 5.

Removal of Instrument Case

Remove the two screws along the lower edge of each front panel section [four screws in all]. Push the voltmeter rear panel until the display unit projects far enough from the case to be gripped. The complete instrument may now be withdrawn from the case. [Care should be taken to ensure that the Floating Section sub-chassis does not work loose and become accidentally detached from the main chassis.]

Figure 4.7 Removal of Instrument Case

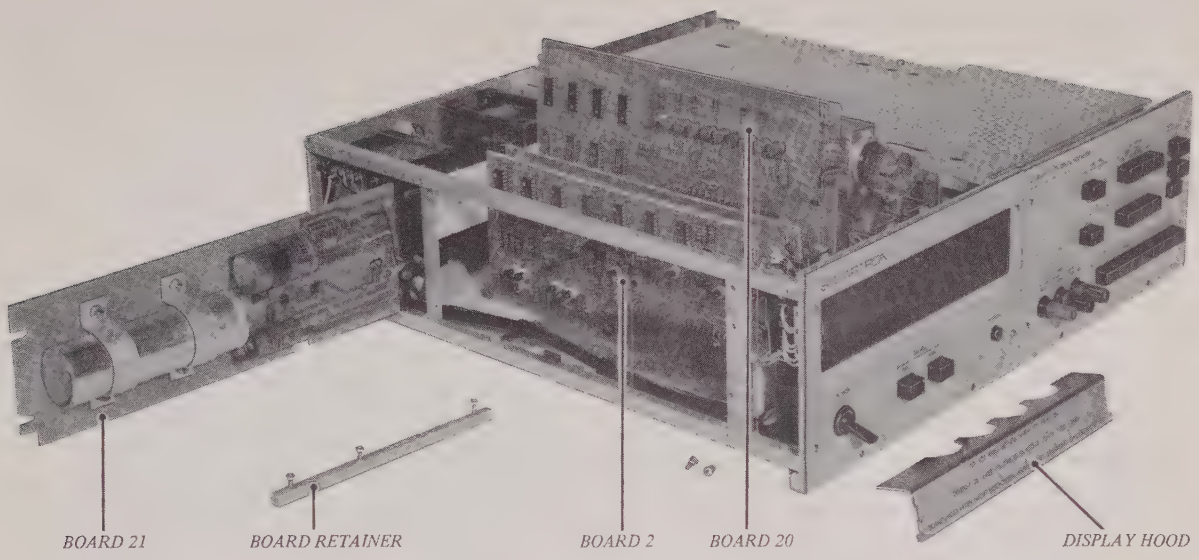


Figure 4.8 Board Location - Display Section

Removal of Board 20

Remove the three screws from the retaining bar fitted across the rear edges of the plug in boards and lift off. Insert a bladed screwdriver into one of the slots provided in the display hood and prise off. The four boards 20 can now be removed by a direct upward pull.

Access to Board 21

This board is fitted to the left side of the chassis and is hinged to swing outwards. Remove the two screws at the front panel end of the board. Apply outwards pressure with the fingertips to the board in the vicinity of the two spring retaining clips situated top and bottom approximately half way along its length. The board will now hinge outwards.

CAUTION
When the power is on, ensure that board 21 is not allowed to hinge back far enough to contact the terminals of the mains transformer mounted on the rear panel.

Removal of Board 2

Remove the retaining bar [See paragraph 'Removal of Board 20'] and hinge out board 21. After the six 'disconnect' terminals have been removed, board 2 can be withdrawn by a direct upward pull.

Removal of Board 22

Board 22 is mounted on two pillars directly below the display panel.

Remove all plug in boards from the main assembly and hinge out board 21. Remove the front printed circuit board guide by undoing two screws at either side and three underneath. Board 22 can now be removed when the two retaining screws are undone.

Refitting of Boards

The four boards 20 are completely interchangeable and may be inserted in any order. Staggering of the sockets on the mother board ensures that incorrect fitting is impossible. Board 2 is physically interchangeable with the EX3055 Auto Range Board [if fitted] and care must be taken to refit in the correct position. After insertion, the 'disconnect' terminals must be pushed firmly on to the relevant pins. Finally, the display hood should be pressed into position above the indicator neons and the board retaining bar re-fitted.

Replacement of V/mV Neons

Two neons are contained in a housing at the front right side of the display chassis. After unsoldering the appropriate two wires, a defective neon can be withdrawn from the housing by a direct horizontal pull.

Replacement of ± and ~ Neons

Three neons are contained in a housing at the front left side of the display chassis. After unsoldering the appropriate two wires, a defective neon can be withdrawn by a direct horizontal pull.

Replacement of Display Tubes

The board containing the defective indicator should be removed. The neon can then be withdrawn by a firm pull.

Replacement of Decimal Point Neons

Boards adjacent to the defective neon should be removed to provide ease of access. After unsoldering two wires the appropriate neon can be removed by a direct pull

Replacement of the Overload Neon

This can be removed after unsoldering the two wires from board 22 which are accessible from below. The neon is integral with its red housing and is secured in place by a spring retaining clip.

Access to Front Panel Controls

All connections to the controls are accessable from below although the POWER ON switch is protected by a rubber cover.

FITTING OF OPTIONAL KITS

EX3055 Auto Range Board

Remove the instrument case. Remove the retaining bar from the display unit. [See paragraph 'Removal of Board 20.] Insert the EX3055 into the vacant position on the mother board [the third socket from the left]. Replace the retaining bar and instrument case.

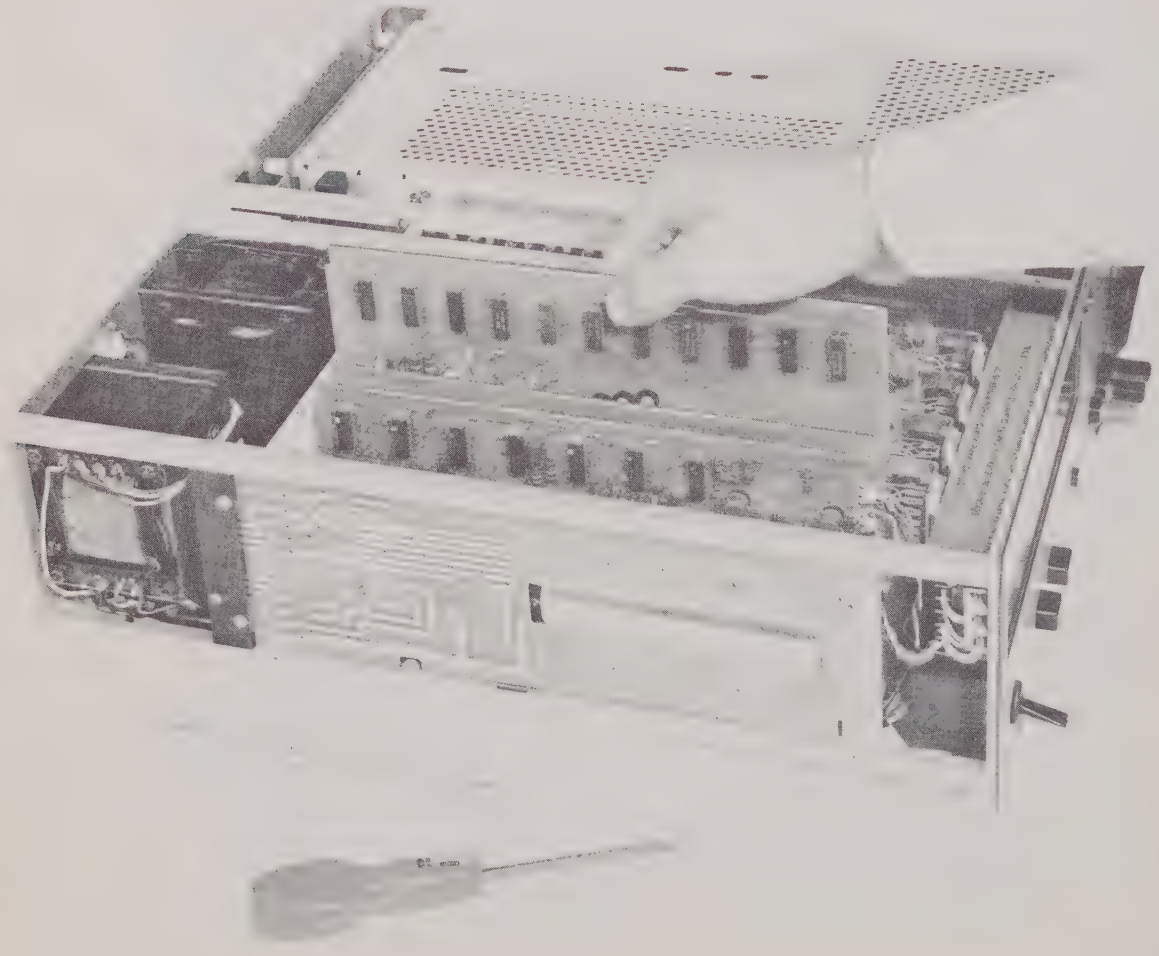


Figure 4.9 Fitting the EX3055 Auto Range Board

Withdraw the floating section from the instrument. Remove the four screws from the front panel and the link from the input terminals. Prise off the LM1604 front panel and replace with the LM1604/05 front panel. Secure with the four screws and replace the link.

Remove the perforated top cover. Undo the four screws securing the rear portion of the right side chassis which can then be removed and fit the chassis with the EX1605 boards 1 and 3 attached into the space vacated. Mate the free plug PLA on the 1605 chassis with the fixed socket at the rear of the 1604 chassis.

Plug 1605 board 2 into the vacant socket on the mother board and re-assemble the instrument.

NOTE
Where the later version one-piece front panel has been supplied as a part of the EX1605 A.C. Unit, the front panels on the display and floating sections must both be removed and replaced. This necessitates withdrawing the complete voltmeter from its case and removing the display section front panel by undoing the four Pozidrive screws from around its edge.

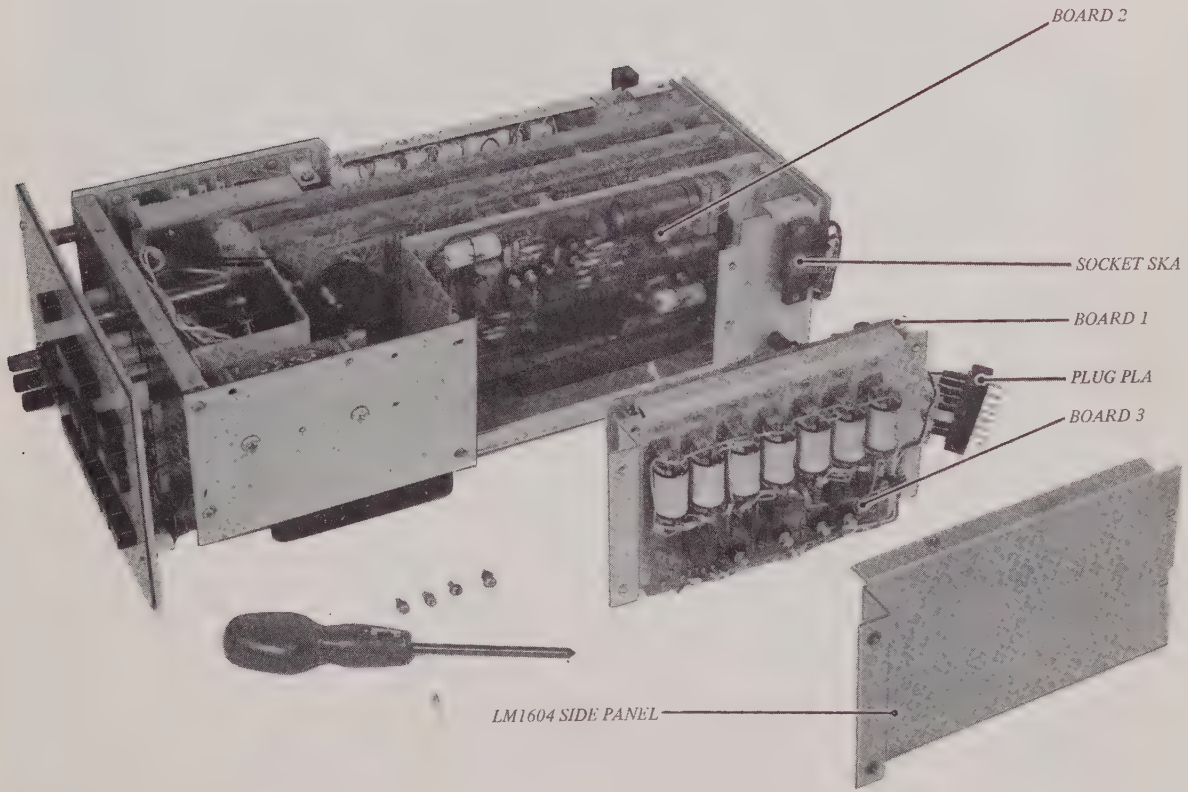


Figure 4.10 Fitting the EX1605 AC Kit

EX3052 and EX3054 Fan Out Units

Both units can be fitted without removing the instrument case. Remove the two screws holding the plate in position on the rear panel of the voltmeter. Insert the Fan Out Unit into the recess revealed when the plate has been removed and push home ensuring correct alignment between the board and its guide. Secure the Fan Out Unit by refitting the two screws removed from the cover plate.

Figure 4.11 Fitting a Fan Out Unit

DISMANTLING OF FAN OUT UNITS

Both the EX3052 and EX3054 Fan Out Units are of similar construction. For servicing, the two boards can be separated after removing the four fixing screws at the corners of board 2.

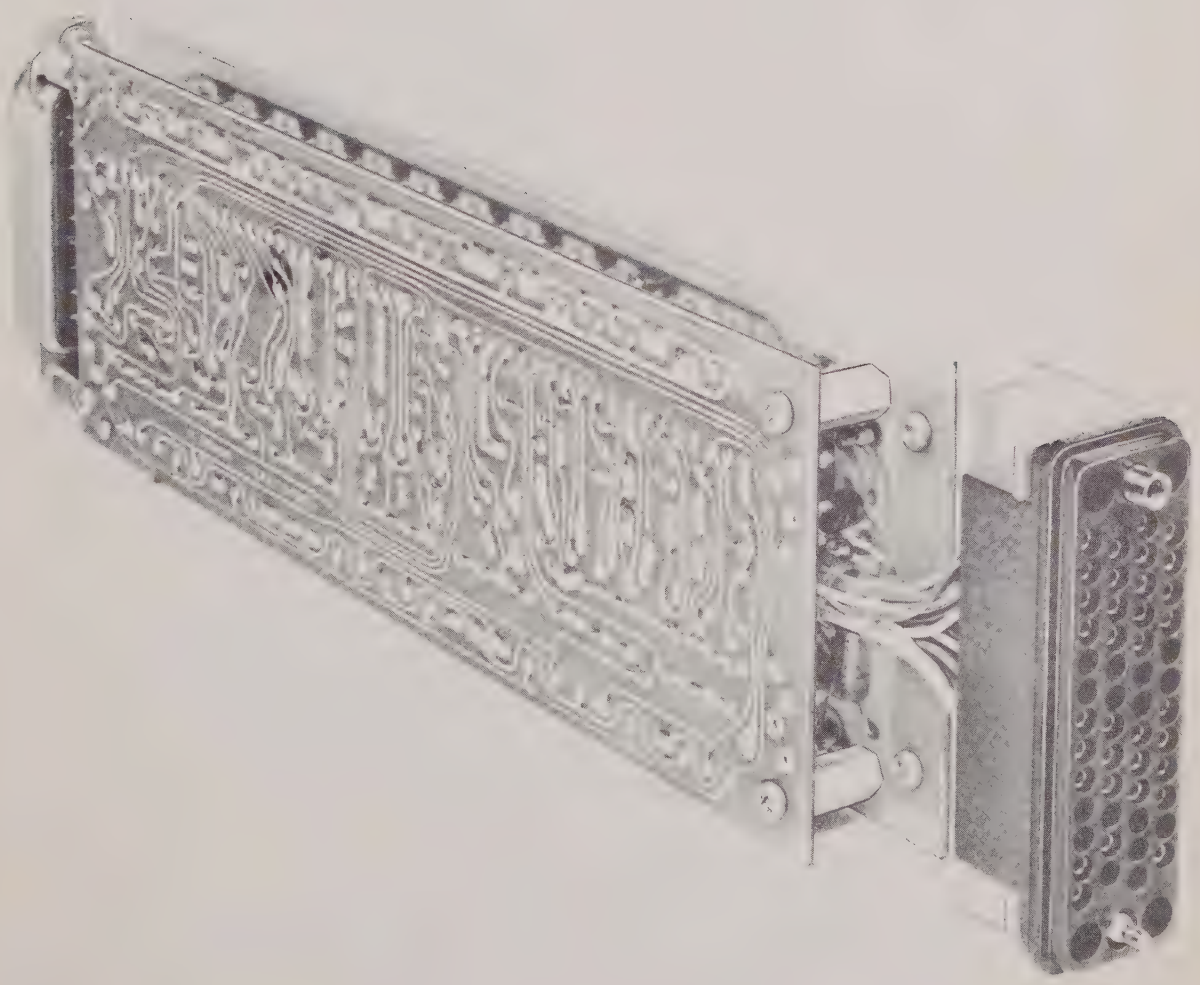


Figure 4.12 Fan Out Unit – Physical Construction.

LM1604 VOLTMETER TEST PROCEDURE

Recommended Test Equipment

Solartron CD1400 Oscilloscope with EX1442 plug in unit.

Kintel Voltage Standard Type 303B.

Dekavider DV54 Decade Box [0.001% Linearity].

Variac

Avometer model 8.

Solartron Digital Voltmeter LM1420.

Comark Thermocouple Multimeter, Type 1621.

Solartron Frequency Counter Type EM1616.

Muirhead Reference Cell [1.018V].

Detailed Tests

Preliminary

Switch the voltmeter on and allow 1 hour before making any adjustment.

Rail Voltages

Fit the dummy load board shown in Figure 4.13 in the EX1605 board 2 socket and set the mains input to 230 volts ±5 volts.

Measure the voltage between pin 18 [0V] and pin 19 of the mother board and adjust RV1 on board 6 to give +20 ±0.2 volts

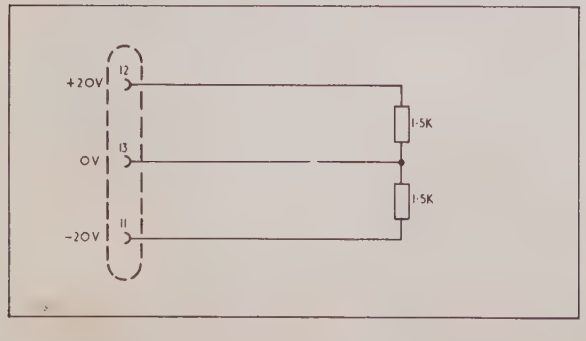


Figure 4.13 EX1605 Dummy Load Circuit.

CHECK the voltages in table 4.1 with respect to the 0V rail.

Collector of the 2N3054 power transistor VT3	+30 ±5	Volts
Pin 4 board 5	-40 ±2	Volts
Pin 5 board 5	+40 ±2	Volts
Pin 7 board 5	+6 ±0.5	Volts
Pin 8 board 5	-20 ±1	Volts
Pin 9 board 5	+20 ±1	Volts
Between pins 13 and 12 board 5	+20 ±1	Volts
Between pins 13 and 11 board 5	-20 ±1	Volts
Between pins 16 and 15 board 5	-25 ±1	Volts

Table 4.1 LM1604 Rail Voltages

Inverter Frequency

Examine the waveform at VT1 collector on board 5 which should be a square wave of about 40 volts amplitude with a period of 34 ±8μsec. Make sure there is no high frequency oscillation on the waveform.

Remove the dummy load and check that the inverter waveform is still correct.

Oven Temperature

Remove the cover from the oven on board 3, and insert a thermocouple or thermistor into the zener hole in the oven. Gradually adjust RV3 anticlockwise until the oven temperature is 67°C ±2°C.

Remove the thermocouple and refil the hole with heatsink compound. Replace the oven cover.

20 volt Zero

Switch to the 10V range, DC FILTER OUT and feed in 10-11mV [flicker point]. Adjust RV1 on board 3 so that the reading is the same magnitude when the input leads are reversed.

Positive/Negative Error

Switch to the 1V range, filter out, apply about -1.9 volts and make a note of the reading. Reverse the input leads and adjust RV2 on board 3 so that the magnitude is the same as for the negative reading.

Chopper Spikes

With an oscilloscope set to a sensitivity of at least 1mV/cm look at the waveform on test point 2 [TP2]

on board 10. The oscilloscope should be triggered externally by the waveform at the junction of R37, R38 on board 5 and its earth taken to the chopper box. Adjust C13 on board 10 for minimum spikes until the waveform of figure 4.14 is obtained. The peak to peak amplitude of this waveform should be <1mV. [This adjustment should be carried out with a non-conducting screwdriver.]

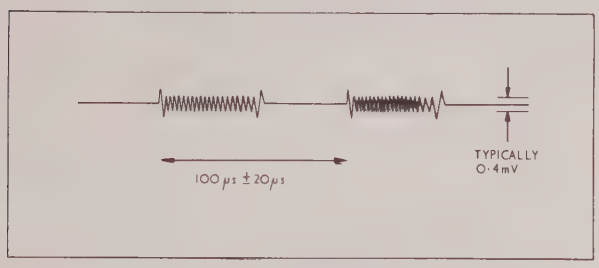


Figure 4.14 Chopper Spikes – Optimum Adjustment

Temperature Compensation Circuit

With the input disconnected select the 10mV range. Adjust RV2 on board 10 to an end stop. Press the µV ZERO button and adjust the µV ZERO potentiometer to bring the display to 0.000. Set RV2 to the other end stop and adjust RV1 to bring the display back to zero. Repeat this procedure until adjustment of RV2 from one end stop to the other makes no difference to the display.

Voltage Zero

Press the µV ZERO button and check that an adjustment of ±20µV can be achieved with the front panel control. Adjust for zero on the display.

Current Zero

Switch to the 10mV range with the µV NOISE filter in. Fit a 1MΩ resistor in parallel with a 1µF capacitor between the input HIGH and LOW terminals. Adjust RV1 on board 5 to give a reading of <±5µV.

Repeat the voltage zero and current zero adjustments until both are correct.

Voltage Zero Error

With a short circuit on the input terminals on the 10mV range the reading on each of the three DC filter positions should be <±2µV.

Zener Calibration

Press the CAL button and check that an adjustment of 10 bits on either side of the CAL voltage can be obtained.

Clock Adjustment

Short circuit C10 on board 1. Connect a counter to R40 and adjust RV1 to give a clock frequency of 2MHz ±20kHz.

Remove the short circuit and check that the clock frequency adjust bistable is switching [TP1].

Decimal Point Position and Annunciators

Switch to each range in turn, checking that the decimal point appears in the correct position and that the V and mV signs are displayed as appropriate. Check that positive polarity is displayed on the CAL position and that the A.C. sign is illuminated when the A.C. button is selected.

Input Impedance

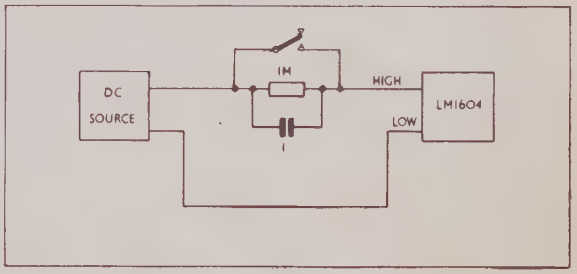


Figure 4.15 Measurement of Input Impedance

Apply 10 000 bits on the 10V range and 18 000 bits on the 1V, 100mV and 10mV ranges as shown in figure 4.15. On the 10V range the error should be <1 bit when the switch is closed. On the 1V and 100mV ranges the error should be <2 bits. On the 10mV range the error should be <18 bits. [On the 10mV range, take the mean of the errors on positive and negative readings. The error should never be greater than 50 bits on either polarity.]

Series Mode Rejection

Connect the voltmeter as in figure 4.16. Adjust the d.c. source to give a reading of 10-11 bits on the 10V range. Press the DC FILTERS OUT button. Increase the series mode signal until the reading changes by 1 bit, when the a.c. signal should be <2.2V R.M.S. Switch off the series mode signal and decrease the input voltage to give 10-11 bits on the 1V range. Switch in the 40dB filter and increase the a.c. series mode signal until the reading changes by 1 bit. This voltage should be >22V R.M.S.

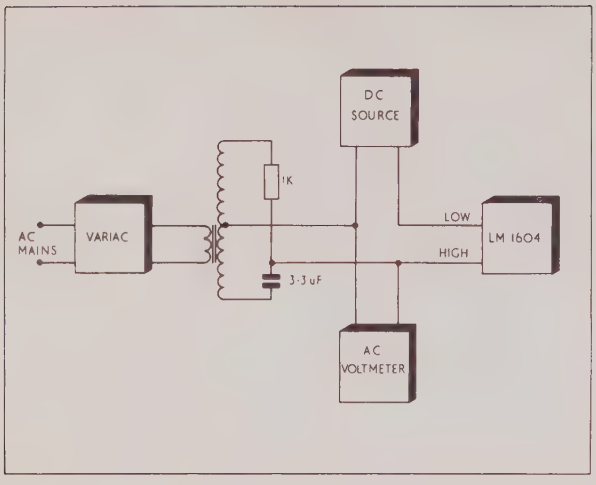


Figure 4.16 Measurement of Series Mode Rejection.

A.C. Common Mode Rejection

Connect the voltmeter as in figure 4.17. Switch to the 100mV range with the d.c. filter OUT. Adjust the d.c. source to give a reading of 10-11 bits. Increase the a.c. common mode signal until the reading changes by 1 bit. The a.c. voltage should be >70V R.M.S.

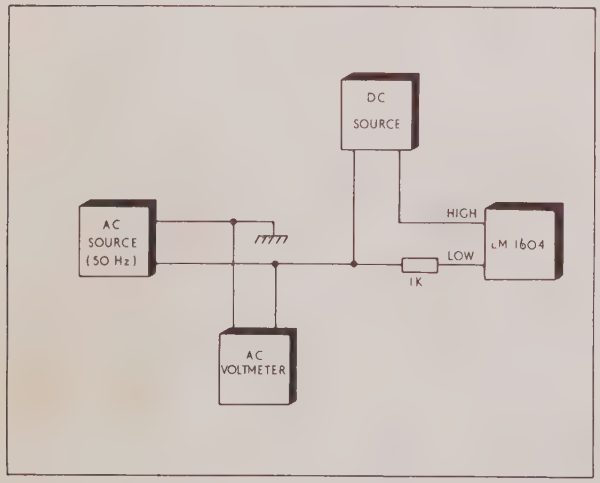


Figure 4.17 Measurement of A.C. Common Mode Rejection

D.C. Common Mode Rejection

Connect the voltmeter as in figure 4.18. Switch to the 100mV range with the 40dB filter in. Apply 500 volts to the HIGH terminal. The reading should be <50mV.

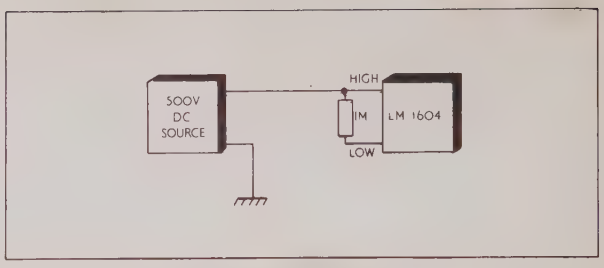


Figure 4.18 Measurement of D.C. Common Mode Rejection

Low to Guard Insulation

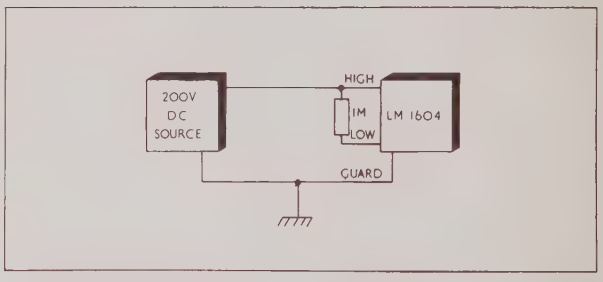


Figure 4.19 Measurement of Low/Guard Insulation

Connect the voltmeter as in figure 4.19. Apply 200 volts to the HIGH terminal. The reading should be <200mV.

Overload Current

Switch to the 10mV range with the D.C. FILTER OUT button pressed. Apply ±200 volts and measure the input current with an AVO which should be <1.5mA.

Remote Ranging

Switch to REMOTE. Apply 0V to pins 21, 22, 23, 24, 25 and 26 of socket SKB and check that the voltmeter switches to ranges 10mV, 100mV, 1V, 10V, 100V and 1 000V respectively. On the 1V range check that there is no difference between readings obtained on remote or local operation.

Floating Box Capacitance

Measure the capacitance between the LOW/GUARD terminals [strapped together] and earth which should be <600pF.

Switch to the 10mV range with the D.C. FILTER OUT. Apply about 1mV from a battery box. The display should not jitter by more than ±1μV. Switch the μV NOISE filter in when a steady reading should be obtainable.

Range Calibration

10V

Switch to the 10V range with the D.C. FILTER OUT. Set the Kintel voltage standard to 20 volts and the decade divider to .90000. Adjust the CAL. control on the front panel to bring the reading to -18.000. Reverse the input leads and check that there is no positive/negative error. If there is an error repeat the 20V zero and the Positive/Negative Error tests.

10mV

Set the divider box to give 18mV out [.00090]. Switch to the 10mV range and select the μV NOISE filter. Adjust RV5 on board 4 to bring the reading to 18.000mV. Reverse the polarity of the input and adjust the μV ZERO control to remove any positive/negative error.

Reset RV5 so that the reading is 18.000mV on both polarities. Short circuit the input leads where the reading should be <1μV.

100mV

Switch to the 100mV range with the DC FILTER OUT. Feed in 180mV from the decade divider and adjust RV4 on board 4 to give the correct reading, checking for positive/negative errors as before which should now be <10μV.

1V

Switch to the 1V range and with an input of 1.8V adjust RV2 for the correct reading.

100V

Remove the decade divider and apply 190 volts on the 100V range. Adjust RV1 and check that the positive/negative error is <0.01V.

1 000V

Switch to the 1 000V range and feed in 1 000 volts from the Kintel. The positive/negative error should be <0.1V.

Switch the output voltage of the Kintel to zero and remove the input lead. Press the CAL. button and adjust RV3 to give a reading of +10192

Linearity

Check the linearity on the 10V and 10mV ranges by changing the input in steps of 2 000 bits. Linearity errors should be <1 bit.

Temperature Tests and Set Up

Seal chopper box holes and fit the top and bottom covers to the instrument. Allow the temperature to stabilise for 2 hours.

Adjust the voltage and current zeroes and CAL. [using an external cell]. Place the instrument in an oven at 50°C and allow to stabilise for >3 hours. Press the μV ZERO button and adjust RV2 on board 10 to bring the reading back to zero. Fit the sticky label over the holes in the chopper box.

Measure the input current as for the Current Zero check. The reading should now be $\leq \pm 100$ bits. Switch to the 1V range and measure an external standard cell of known voltage using both polarities of the voltmeter. The reading error should be $\leq \pm 3$ bits. Press the CAL. button when the reading should be 10192 ± 6 bits.

Remove the instrument from the oven and allow to cool for 3 hours. Press the μV ZERO button when the reading should be <3 bits. If the reading is greater than this, repeat the oven set up procedure.

Final Calibration

NOTE:
The following checks must be done in a temperature controlled environment at 20°C.

Feed in 18.0V on the 10V range and adjust the CAL. control for a reading of 18000. Check for positive/negative error.

Feed in the inputs on the ranges indicated in table 4.2 adjusting the respective potentiometers on board 4 as necessary.

Range	Input	Adjust	Reading
10mV	18mV	RV 5	18.000 errors 1μV
100mV	180mV	RV 4	180.00 errors <10μV
1V	1.8V	RV 2	1.8000 errors <100μV
100V	190V	RV 1	190.00 errors <0.01V
1 000V	1 000V	-	1000.0 errors <0.1V

Table 4.2 LM1604 Final Calibration

NOTE:
All ranges are to be checked on both polarities. Positive/negative errors should be less than 1 bit.

Press the CAL. button and adjust RV3 on board 4 to give a reading of 10192.

Check the linearity on the 1V and 10mV ranges. When the input is changed in 2000 bit steps the linearity error should be <1 bit.

Check that on all three filter positions the difference in the zero obtained when the input terminals are short circuited and when the μV ZERO button is pressed is <2μV.

Modification for 60Hz Operation

When used on 60Hz mains supplies, a minor modification is necessary to ensure that 20 000 clock pulses are still produced in one mains period [i.e. 16.6 msec.]. This consists of replacing C13 on board 1 with a 220p capacitor of similar type as detailed in the parts list.

LM1604 SOCKET SKB	FUNCTION	PRINTER FREE PLUG
1	1	1
2	2	2
3	4	3
4	8	4
5	10	5
6	20	6
7	40	7
8	80	8
9	100	9
10	200	10
11	400	11
12	800	12
13	1000	13
14	2000	14
15	4000	15
16	8000	16
17	10000	17

Table 4.3 LM1604/Kienzle Printer Interconnections

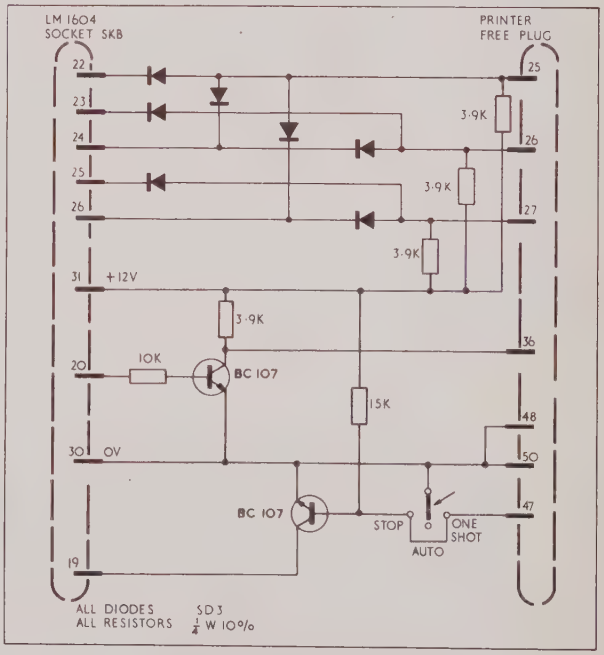


Figure 4.20 LM1604/Kienzle Printer Interface Circuit

EX 1605 AC UNIT TEST PROCEDURE

Recommended Test Equipment

Weston-Rotek Continuously Variable Oscillator [CVO] Model 100 with a High Resolution Voltage Divider Model 111.

Weston Precision Amplifier Model HVA-120.

Rotek AC Absolute voltage standard Model 150.

Tektronix Type 130 L-C Meter.

Kienzle Type D4-E line printer with the appropriate interface [refer to figure 5.8].

Gertsch Ratio Transformer Model RT-7.

AVO meter Model 8.

500V Megger Insulation Tester.

Solartron LM1604 Digital Voltmeter.

Solartron CD1400 Oscilloscope.

Cambion 2375-1 trimming tool.

Resistor 1kΩ ±1% metal oxide.

Detailed Tests

CAUTION
The maximum permitted overload on the 100mV and 1V ranges is 250V i.e. 175V r.m.s. sine wave.

Isolation and Short Circuit Checks

Before inserting the boards comprising the EX1605 a.c. kit, carry out the following tests.

On board 1 check that the insulation resistance between plug PLA pin 3 and chassis is >100MΩ.

On board 3, check that the insulation resistance between plug PLA [free] pin 7 and chassis is >100MΩ.

Plug the three boards of the EX1605 a.c. kit into the LM1604 voltmeter. Connect a link between the HIGH, LOW and GUARD terminals on the front panel.

Depress the following push-button controls -25/s, AC, 1s, 750V MAX, DC FILTERS OUT. Switch on the LM1604.

Zero Checks

The reading after 1 minute should be <000.6V.

Select the 100V range when the reading after 3 seconds should be <00.06V.

Select the 10V range when the reading after 3 seconds should be <0.006V.

Select the 1V range when the reading after 3 seconds should be <.0006V.

Select the 100mV range when the reading after 3 seconds should be <00.06mV.

Select the 750V range and remove the link from the input terminals. The capacitance between the HIGH and LOW terminals should be <100pF.

Select the 1V range. The capacitance between the HIGH and LOW terminals should be <150pF.

1V Range Calibration

Connect the CVO 100 200Ω output to the HIGH and LOW terminals. Set the frequency to 1kHz and adjust the amplitude so that the LM1604 reads 1.9005. Reduce the frequency until the figure displayed in the least significant window jitters by ±1 digit [i.e. a 3 digit spread]. Check that the frequency of the input is <350Hz.

Select the 3 sec AC response time and reduce the frequency until the jitter in the lease significant window is ±1 digit. Check that the frequency of the input is <50Hz.

Select the 10sec AC response time and reduce the frequency until the jitter in the lease significant window is ±2 digits. Check that the frequency of the input is <15Hz.

The appropriate AC FILTER should now be selected as necessary during the following calibration checks.

1V Range Calibration

Disconnect the CVO 100 oscillator and substitute the ROTEK 150. Select 1.9500 volts at 400Hz. Adjust the AC SCALING 2V control RV1 on board 1 to give a reading of 1.9500 on the display.

Linearity

Check the linearity of the 1V range as detailed in table 4.4.

ROTEK OUTPUT	LM1604 DISPLAY	TOLERANCE
1.5000V 1.0000V 0.5000V 0.1000V 0.0500V — 400Hz	1.5000V 1.0000V 0.5000V 0.1000V 0.0500V —	±6 bits

Table 4.4 EX1605 Linearity – 1V Range

Connect the Gertsch ratio transformer between the ROTEK 150 and the LM1604. Set the ratio to X0.1 and the ROTEK to 1.9500 volts. Select the 100mV range on the LM1604 and adjust the transformer ratio to give a reading of 195.00mV

Reset the Rotek to 1.5000V and check the linearity as in table 4.5.

Disconnect the ratio transformer.

ROTEK OUTPUT	RATIO TRANSFORMER SETTING	LM1604 DISPLAY	TOLERANCE
1.5000V 1.0000V 0.5000V – 400Hz 0.1000V 0.0500V	X0.1	150.00mV 100.00mV 50.00mV – 10.00mV 05.00mV	±6 bits

Table 4.5 EX1605 Linearity – 100mV Range

100V Range Calibration LF

Select the 100V range on the LM1604 and 195.00 volts on the ROTEK 150. Adjust the ÷100 LF control RV1 on board 1 to give a reading of 195.00 on the display.

750V LF

Select the 750V range on the LM1604 and 750.0 volts on the ROTEK 150. Adjust the ÷1000 LF control RV2 on board 1 to give a reading of 750.0 on the display.

750V HF

Reset the ROTEK 150 to 20kHz. Adjust the ÷1000 HF control C17 on board 1 to give a reading of 750.0 ±14 bits. Reset the ROTEK 150 to 5kHz and check that the LM1604 still displays 750.0 ±14 bits.

10V

Select 19.500V at 400Hz on the ROTEK 150 and the 10V range on the LM1604. Adjust the AC SCALING 200mV control RV2 on board 2 to give a reading of 19.500.

100mV

Select X .01 on the ratio transformer and interpose this between the ROTEK 150 and the LM1604. Select the 100mV range on the LM1604 and check that the reading is 195.00 ±10 bits. If these limits are exceeded, readjust RV2 and check that the 10V range calibration is also within the limits [ignoring the decimal point].

Frequency Response 1V Range

Remove the ROTEK 150 and ratio transformer. Connect the CVO 100 oscillator to the LM1604 using the attenuated output. Set the frequency to 400Hz and select the 1V range on the LM1604. Adjust the output of the oscillator to give a reading of 1.9500 and check the frequency response as in table 4.6.

CVO 100 OUTPUT	LM1604 DISPLAY	TOLERANCE
1.9500V – 20Hz	– 1.9500V	±45 bits
30Hz		±25 bits
5kHz		±25 bits
20kHz		±45 bits
50kHz		±103 bits
100kHz		±400 bits

Table 4.6 EX1605 Frequency Response – 1V Range

100V Range Calibration HF

Select the 100V range on the LM1604. Set the CVO 100 oscillator to 400 Hz and route its output via the HVA-120 amplifier. Adjust the output to give a reading of 120.00 volts on the LM1604. Reset the frequency to 50kHz and adjust the ÷ 100 HF control C16 on board 1 to give a reading of 120.00 volts on the LM1604. Set the HVA-120 to "STANDBY".

Frequency Response 10V Range

Select the 10V range on the LM1604 and adjust the voltage input to give a reading of 19.500 volts at 400Hz. Check the frequency response as in table 4.7.

HVA 120 OUTPUT	LM1604 DISPLAY	TOLERANCE
19.500V – 20Hz	– 19.500V	±45 bits
30Hz		±25 bits
5kHz		±25 bits
20kHz		±45 bits
50kHz		±152 bits
100kHz		±400 bits

Table 4.7 EX1605 Frequency Response – 10V Range

Frequency Response 100V Range

Selected the 100V range on the LM1604 and adjust the input to give a reading of 120.00 volts at 400Hz. Check the frequency response as in table 4.8.

[Share the errors between the 10V and 100V ranges.]

HVA 120 OUTPUT		LM1604 DISPLAY	TOLERANCE
120.00V—	20Hz	—120.00V	±30 bits
	30Hz		±18 bits
	5kHz		±18 bits
	20kHz		±30 bits
	50kHz		±96 bits
	100kHz		±240 bits

Table 4.8 EX1605 Frequency Response – 100V Range

Frequency Response 750V Range

Select the 750V range on the LM1604 and adjust the input to give a reading of 120.00 volts at 400Hz. Check the frequency response as in table 4.9.

HVA 120 OUTPUT		LM1604 DISPLAY	TOLERANCE
120.00V—	20Hz	—120.00V	±80 bits
	30Hz		±70 bits
	5kHz		±70 bits
	20kHz		±80 bits
	50kHz		±150 bits
	100kHz		±240 bits

Table 4.9 EX1605 Frequency Response – 750 Range

Overload Recovery

Disconnect the HVA-120 amplifier from the LM1604. Depress the AC RESPONSE TIME 1s push button.

Connect the KIENZLE printer to the LM1604 using the interface circuit to figure 4.20. Set the ROTEK 150 to 1kHz and 18.000 volts. Set the ratio transformer to 0.1 and connect it between the ROTEK 150 and the LM1604. Select the 1V range on the LM1604 and adjust the ROTEK to give a reading of 1.8000. Increase the ratio transformer setting to 0.2 for 5 seconds then start the printer simultaneously resetting the ratio transformer to 0.1. When the reading settles at 1.8000 stop the printer. Check that the time taken for the record to settle within 1.8000 ±18 bits is <6 seconds. [The printer can be controlled by the 25/s [off] and the MANUAL [on] push buttons].

Set the ratio transformer to 0.01 and select the 100mV range on the LM1604. Adjust the input to give a reading of 180.00mV. Increase the ratio transformer setting to 0.02 for 5 seconds, then start the printer simultaneously resetting the ratio to 0.01. When the reading is steady at 180.00 stop the printer. Check that the time for the record to settle to 180.00mV ±18 bits is <6 seconds.

Step Response

1s

Set the ratio transformer to zero. Start the printer and reset the ratio transformer to 0.01. When the reading is steady at 180.00 stop the printer. Check that the time taken for the record to settle to 180mV ±18 bits is <1 second.

3s

Set the LM1604 to AC RESPONSE 3s and repeat the step response test. The record should now settle in a time <3 seconds.

10s

Set the LM1604 to AC RESPONSE 10s and repeat the step response test. The record should now settle in a time <10 seconds.

Range Change

Select AC RESPONSE 1s. Start the printer then select the 1V range on the LM1604. When the reading is steady at .1800 stop the printer. Check that the time for the record to settle to .1800 ±7 bits is <3 seconds.

Repeat the preceding test but selecting the 100mV range. The time for the reading to settle to 180.00 ±18 bits should be <3 seconds.

Select the 1V range on the LM1604 and adjust the input to give a reading of 1.8000 volts. Start the printer then select the 10V range. When the reading is steady at 1.800 stop the printer. Check that the time taken for the record to settle to 1.800 ±7 bits is <3 seconds.

Start the printer, then select the 1 volt range on the LM1604. When the reading is steady at 1.8000 volts stop the printer. Check that the time taken for the record to settle to 1.8000 ±18 bits is <3 seconds.

Crest Factor

Connect the oscilloscope to the 320μF 4V capacitor [C19] on board 2 [either end]. Increase the input voltage until clipping of the peaks is just noticeable. Reduce the input by 0.1 volt r.m.s., and check that the dial reading is >3.8V r.m.s. Remove the input signal.

Common Mode Rejection Ratio

Connect the 1kΩ 1% resistor between the LM1604 input terminals HIGH and LOW. Connect the ROTEK 150 oscillator between HIGH and chassis [not GUARD]. Strap the GUARD terminal to LOW. Select AC RESPONSE 10s. Set the frequency to 50Hz and the input amplitude to 350V r.m.s. Check that the LM1604 reads <.4956 volts. Reduce the input to zero.

Re-strap GUARD to HIGH. Increase the input to 350V r.m.s. and check that the LM1604 reads <.0501 volts. Remove the input signal.

EX3055 TEST PROCEDURE

Recommended Test Equipment

Solartron LM1604 Digital Voltmeter.

Solartron EX3054 Fan Out Unit

Solartron CD1014 Oscilloscope

Stabilised d.c. Power Supply 0-250 Volts

Four Decade Voltage Divider.

Detailed Tests

LM1604 Performance Check

Carry out normal setting up procedure for LM1604 and test according to the specification without EX3055 inserted.

Auto Range Interference

Do not insert EX3055.
Set controls of LM1604 as follows:-
25/s Sample
DC
Filter OUT
Range 10V
Switch power on and apply an input of approximately 15V. Note the displayed reading. Without altering the controls, switch off LM1604, insert EX3055, switch on. Check if reading agrees with respect to sign, magnitude, decimal point and Volt/millivolt sign with previous reading ±10mV. If these do not check do not proceed with tests.

Select AUTORANGE, but otherwise do not alter controls or input voltage. Check if displayed reading agrees with previous reading with respect to sign, magnitude, decimal point, and Volt/Millivolt sign ± 10mV.

Range Change Points

Increase the input voltage slowly through 19.000 volts. Check that at 19.000 the unit changes to 100V range. Note final reading.
Select the 100V range and check that the reading displayed agrees with the last noted reading with respect to polarity, magnitude, decimal point position and Volt/Millivolt sign ± 10 mV.

Re-select AUTO RANGE.
Reduce the input voltage slowly through 18.00 Volts. Check that unit changes to 10V range.

Range Selection

With reference to table 4.10 apply an input voltage approximately equal to that in the first row of column A. Note reading with AUTO RANGE selected in column B. Switch to range designated in column C. Note reading in Column D. Check whether column B entry agrees with respect to polarity, magnitude, decimal point position and volt/millivolt sign.

NOTE:
[1] For 210V input the content of columns B and D should be 199.99V.

[2] Tolerance on Auto Range readings is ± 2 bits.

A Input	B Reading on Auto-range	C Range to which manual should be switched	D Reading on manual range
10mV		10mV	
100mV		100mV	
1V		1V	
10V		10V	
100V		100V	
210V		100V	

Table 4.10 Accuracy of Auto Range Readings

Delay Monostable Operation

With AUTO RANGE and 25/s SAMPLE selected, check that waveform at VT3 collector is as shown in figure 4.21.

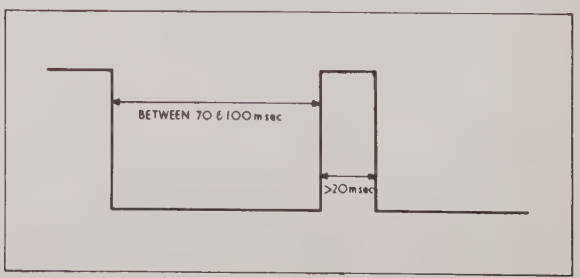


Figure 4.21 VT3 Collector Waveform

Manual Sampling with Auto Range

Select AUTO RANGE and MANUAL SAMPLE
Apply input [1] as in table 4.11
Manual sample twice, noting each reading.
Check that the two noted figures agree with respect to polarity, decimal point position, magnitude and V/mV sign.

Leave input [1] reading displayed whilst changing the input to that of value given by [2] in table 4.11.

As before, sample twice noting each reading and checking for agreement. Leaving input [2] displayed change to input [3].
Proceed through the table in this fashion.

NOTE [1]
After [3] Zero input need not be sampled twice.

NOTE [2]
The 210V input should give a display of 199.99 volts.

Input	1st Manual Sample	2nd Manual Sample	Limits
1. Zero			± 2 bits
2. 210V			± 2 bits
3. Zero			± 2 bits
4. 150V			± 2 bits
5. Zero			± 2 bits
6. 15V			± 2 bits
7. Zero			± 2 bits
8. 1.5V			± 2 bits
9. Zero			± 2 bits
10.150mV			± 2 bits
11. Zero			± 2 bits

Table 4.11 Manual Sampling Accuracy

Print Command

Switch off LM1604.
Insert Fan Out Unit EX3054.
Connect upper beam probe of oscilloscope to VT4 Collector [Can].
Set volts/cm control to 5V/cm d.c.
Connect lower beam probe to pin v of EX3054. [Normal mode].

Switch on LM1604.
Set AUTO RANGE.
Set oscilloscope trigger selector control to external negative.
Set scope time/cm control to 200 msec.
Adjust Oscilloscope trigger stability/sensitivity controls so that pressing the LM1604 MANUAL SAMPLE button causes the beam to traverse the screen once.
Apply an input of 30V [approximately].

Operate the MANUAL SAMPLE button.
Whilst leaving the previous 30V reading displayed, apply zero volts with the μV ZERO control.

When the MANUAL SAMPLE button is pressed a display as in figure 4.22 should appear.

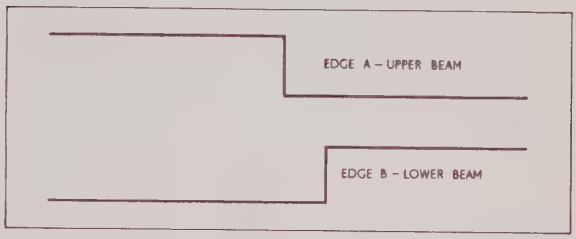


Figure 4.22 Print Command Signal

Check that the display is as in figure 4.22 and that edge B occurs after edge A.

NOTE
The waveform may only be re-observed by repeating this procedure

Switch off LM1604
Connect oscilloscope external trigger probe to VT4 Collector [Can].
Change oscilloscope time/cm control to 50 msec/cm.
Apply 30V [approximately].
Press the MANUAL SAMPLE button [NOTE: This operation will not cause a trace on the screen].
Press the μV ZERO button and MANUAL SAMPLE.
A trace should appear as in figure 4.23.

NOTE
Waveform may only be re-observed by repeating this procedure.

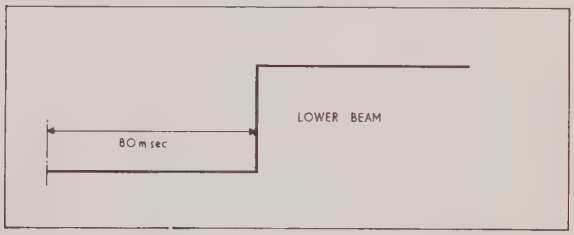


Figure 4.23 Print Command Delay

EX3054 TEST PROCEDURE

Recommended Test Equipment

Solartron LM1604 Voltmeter

Solartron CD1400 Oscilloscope

Variable D.C. Power Supply

Pulse Generator with an output positive with respect to earth.

Detailed Tests

Plug the EX3054 into the LM1604. Set the LM1604 controls to DC mode, 1V range, sample 25/s and connect a variable voltage source to the input terminals.

BCD 7_0

Set the voltage source to give a reading of 7 on the least significant [fifth] digit of the display. Check the output of the following pins with the Avometer.

Pin	Voltage
A	12 ± 3V
B	12 ± 0.5V
C	12 ± 0.5V
D	< 0.5V

BCD 8_0

Set voltage source to give a reading of 8 on the least significant digit of the display. Check the output on the following pins.

Pin	Voltage
A	< 0.5V
B	< 0.5V
C	< 0.5V
D	12 ± 0.5V

BCD 7_1

Set the voltage source to give a reading of 7 on the fourth digit of the display. Check the output on the following pins.

Pin	Voltage
E	12 ± 0.5V
F	12 ± 0.5V
H	12 ± 0.5V
J	< 0.5V

BCD 8_1

Set the voltage source to give a reading of 8 on the fourth digit of the display. Check the output on the following pins:

Pins	Voltage
E	< 0.5V
F	< 0.5V
H	< 0.5V
J	12±0.5V

BCD 7_2

Set the voltage source to give a reading of 7 on the third digit of the display. Check the output on the following pins:

Pins	Voltage
K	12±0.5V
L	12±0.5V
M	12±0.5V
N	< 0.5V

BCD 8_2

Set voltage source to give a reading of 8 on the third digit of the display. Check output on the following pins:

Pins	Voltage
K	< 0.5V
L	< 0.5V
M	< 0.5V
N	12±0.5V

BCD 7_3

Set the voltage source to give a reading of 7 on the second digit of the display. Check output on the following pins:

Pins	Voltage
P	12±0.5V
R	12±0.5V
S	12±0.5V
T	< 0.5V

BCD 8_3

Set the voltage source to give a reading of 8 on the second digit of the display. Check output on the following pins:

Pins	Voltage
P	< 0.5V
R	< 0.5V
S	< 0.5V
T	12±0.5V

BCD 0_4

Set voltage source to give a reading of 0 [i.e. figure 1 off] on the first digit. Check output on:

Pin	Voltage
U	< 0.5V

BCD 1_4

Set voltage source to give a reading of 1 on the first

digit. Check output on:

Pin	Voltage
U	12 ± 0.5V

Polarity

Set voltage source to give positive reading. Check output on:

Pin	Voltage
d	12 ± 0.5V
e	< 0.5V

Reverse polarity and check output on:

Pin	Voltage
d	< 0.5V
e	12 ± 0.5V

Range Output

Check output on:

Pin	Voltage
f	< 0.5V
h	12 ± 0.5V
j	0.5V

Switch voltmeter to 100mV range. Check output on:

Pin	Voltage
f	12 ± 0.5V
h	< 0.5V
j	< 0.5V

Switch voltmeter to 100V range. Check output on:

Pin	Voltage
f	< 0.5V
h	< 0.5V
j	12 ± 0.5V

Check: Pin k — Voltage < 0.5V [sub-unit output].

Switch to A.C. MODE. Check:

Pin	Voltage
k	12 ± 0.5V

Remote Range

Switch to REMOTE MODE, check display indicates 100V range and check outputs on the following pins.

Pin	Voltage
f	< 0.5V
h	< 0.5V
j	12 ± 0.5V

Connect power supply between pin HH [0V] and pin m [positive] and set to +9V. Connect pin p to 0V. Check that display shows 100mV range and check the outputs on the following pins:

Pin	Voltage
f	12 ± 0.5V
h	< 0.5V
j	< 0.5V

Transfer +9V supply from pin m to pin n and check that the display indicates 1V range. Check the following outputs:

Pin	Voltage
f	< 0.5V
h	12 ± 0.5V
j	< 0.5V

Remove 0V from pin p and transfer +9V supply from pin n to pin p. Check that the display indicates 100V range and check the outputs on the following pins:

Pin	Voltage
f	< 0.5V
h	< 0.5V
j	12 ± 0.5V

Remote Mode

Transfer +9V supply from pin p to pin r. Check that the annunciator shows A.C. mode and check the output on pin k.

Pin	Voltage
k	12 ± 0.5V

Logic Outputs

Switch voltmeter to D.C. MODE, 1V RANGE and set input to give about 1V negative reading with SAMPLE control set to 25/SEC. With the oscilloscope check that the waveforms on pins DD, CC, AA, are as shown.

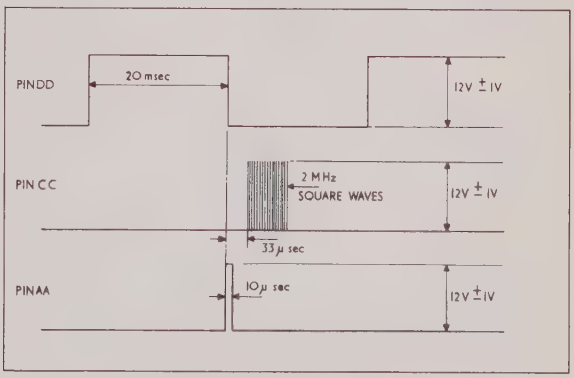


Figure 4.24 EX3054 Logic Outputs

Check output on:

Pin	Voltage
v	< 0.5V

Switch to MANUAL SAMPLE and check output on:

Pin	Voltage
v	12 ± 0.5V

Digitise Command

Connect the pulse generator to pin t and, by varying the input voltage to the LM1604, check that the

instrument does not sample under the following conditions.

Pulse Amplitude	Pulse Width	Pulse Rate
+2V	100μS	20 pps or
+14V	1μS	Single shot

Check that the LM1604 samples with the following pulse input.

Pulse Amplitude	Pulse Width
+8V	10μS

Remove the pulse generator and check that the LM1604 samples when pin s is momentarily connected to pin HH.

EX3052 TEST PROCEDURE

Recommended Test Equipment

LM1604 Voltmeter
Avo Model 8
Pulse generator
Variable voltage source (0-20V minimum)
Power supply (9V)
Solartron CD1400 Oscilloscope

Detailed Tests

Plug EX3052 under test into LM1604
Set LM1604 controls to D.C. MODE, 1V RANGE, 25/SEC SAMPLE, and connect variable voltage source to input terminals. Output voltages are to be measured with respect to pin HH(0V).

BCD 7_0 (Link not fitted between MR19 and R58)
Set the voltage source to give a reading of 7 on the least significant (fifth) digit of the display. Check the output on the following pins with the Avometer:

PIN	VOLTAGE
A	-12 ±3V
B	-12 ±0.5V
C	-12 ±0.5V
	<0.5V

BCD 8_0
Set the voltage source to give a reading of 8 on the least significant digit of the display. Check output on the following pins:

PIN	VOLTAGE
A	<0.5V
B	<0.5V
C	<0.5V
D	-12 ±0.5V

BCD 7_1

Set the voltage source to give a reading of 7 on the fourth digit of the display. Check output on the following pins:

PINS	VOLTAGE
E	-12 ±0.5V
F	-12 ±0.5V
H	-12 ±0.5V
J	<0.5V

BCD 8_1
Set the voltage source to give a reading of 8 on the fourth digit of the display. Check output on the following pins:

PIN	VOLTAGE
E	<0.5V
F	<0.5V
H	<0.5V
J	-12 ±0.5V

BCD 7_2
Set the voltage source to give a reading of 7 on the third digit of the display. Check output on the following pins:

PIN	VOLTAGE
K	-12 ±0.5V
L	-12 ±0.5V
M	-12 ±0.5V
N	<0.5V

BCD 8_2
Set the voltage source to give a reading of 8 on the third digit of the display. Check output on the following pins:

PIN	VOLTAGE
K	<0.5V
L	<0.5V
M	<0.5V
N	-12 ± 0.5V

BCD 7_3
Set the voltage source to give a reading of 7 on the second digit of the display. Check output on the following pins:

PIN	VOLTAGE
P	-12 ±0.5V
R	-12 ±0.5V
S	-12 ±0.5V
T	<0.5V

BCD 8_3
Set the voltage source to give a reading of 8 on the second digit of the display. Check output on the following pins:

PIN	VOLTAGE
P	<0.5V
R	<0.5V
S	<0.5V
T	-12 ± 0.5V

BCD 0_4
Set the voltage source to give a reading of 0 (i.e. figure 1 off) on the first digit. Check output on:

PIN	VOLTAGE
U	< 0.5V

BCD 1_4
Set the voltage source to give a reading of 1 on the first digit. Check output on:

PIN	VOLTAGE
U	-12 ± 0.5V

Polarity
Set the voltage source to give a positive reading. Check output on:

PIN	VOLTAGE
e	-12 ±0.5V
d	< 0.5V

Reverse polarity and check output on:

PIN	VOLTAGE
e	< 0.5V
d	-12 ± 0.5V

Range Output
Set the voltmeter to each range in turn manually and check that the outputs on pins f, h and j are as shown in Table I, where

0 = < 0.5V
1 = -12 ±0.5V

Table 1

Range	pin f	pin h	pin j
10mV	0	0	1
100mV	1	1	0
1V	0	1	0
10V	1	0	0
100V	0	0	0
1000V	1	0	1

Mode Output

Check	PIN	VOLTAGE
	k	< 0.5V

Switch to A.C. MODE. Check:

PIN	VOLTAGE
k	-12 ±0.5V

Remote Range
Switch to REMOTE MODE and set input voltage to zero. Apply a voltage of -9V between pin HH [0V] and pins m, n and/or p according to Table II and check the range displayed for each condition. The output on pins f, h, and j shall be shown in Table II where

0 = < 0.5V
1 = -12 ±0.5V

Table 11

Input	Range	pin f	pin h	pin j
p	10mV	0	0	1
m n	100mV	1	1	0
n	1V	0	1	0
m	10V	1	0	0
	100V	0	0	0
m p	1000V	1	0	1

Remote Autorange
Set input voltage to 100mV. Apply a voltage of -9V to pins m, n and p. Check that the instrument settles on the 100mV range. Increase input voltage to 1V and check that the instrument changes up to the 1V range.

Special Autorange
Remove connections from pins m, n and p and connect pin y to pin FF. Increase input voltage slowly from zero to 20V and check that as each range is indicated the voltages shown in Table III are present on pins m, n and p.

0 indicates < 1V
1 indicates -12 ±1.5V

Table 111

Range	m	n	p
10mV	0	0	1
100mV	1	1	0
1V	0	1	0
10V	1	0	0
100V	0	0	0

Remote Mode
Transfer -9V supply from pin y to pin r. Check that the annunciator shows A.C. mode and check the output on pin k.

PIN	VOLTAGE
k	-12 ±0.5V

Logic Outputs
Switch voltmeter to D.C. MODE, 1V RANGE and set input to give about 1V negative reading with SAMPLE control set to 25/SEC. With the oscilloscope check that the waveforms on pins DD, CC and AA are as shown.

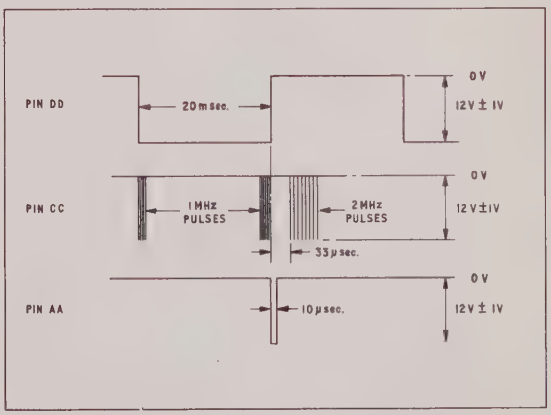


Figure 4.25 EX3052 Logic Outputs

Check output on:

PIN	VOLTAGE
v	< 0.5V

Switch to MANUAL SAMPLE and check output on:

PIN	VOLTAGE
v	-12 ±0.5V

Digitise Command

Connect pulse generator to pin t and by varying the input voltage to the voltmeter check that the instrument does not sample under the following conditions:

Pulse Amplitude	Pulse Width	Pulse Rate
-2V	100μS	20pps
-14V	1μS	single shot

Check that the instrument does sample with the following pulse input:

Pulse Amplitude	Pulse Width
-8V	10μS

Remove the pulse generator and check that instrument samples when pin s is momentarily connected to pin HH.

Power Supply

Using the Avometer, check the following voltages:

PIN	VOLTAGE
EE	+12 ±3V
FF	-12 ±3V

Limited BCD Outputs (Optional link fitted between MR19 and R58)

Set the LM1604 controls to D.C. MODE, 1V RANGE, 25 SEC. SAMPLE

Increase the input voltage to about 1.1V and check the outputs on the following pins with the Avometer.

PIN	VOLTAGE
A	-12 ±0.5V
B	< 0.5V
C	< 0.5V
D	-12 ±0.5V
E	-12 ±0.5V
F	< 0.5V
H	< 0.5V
J	-12 ±0.5V
K	-12 ±0.5V
L	<0. 5V
M	< 0.5V
N	-12 ±0.5V
P	-12 ±0.5V
R	< 0.5V
S	< 0.5V
T	-12 ±0.5V
U	-12 ±0.5V

COMPONENT PARTS LISTS

AND

COMPONENT LOCATION ILLUSTRATIONS

FOR

LM 1604/05

AND

SUB-UNITS

Component Parts List Abbreviations

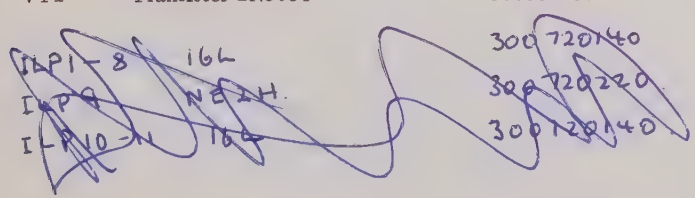
Circuit References	
R	Fixed Resistor [Ω]
RNL	Non Linear Resistor [Ω]
RV	Variable Resistor [Ω]
C	Capacitor [μF]
MR	Diode
L	Inductor
V	Valve
VT	Transistor
IC	Integrated Circuit
RL	Relay
S	Switch
PL	Plug
SK	Socket
MSP	Mains Selector Panel
T	Transformer
FS	Fuse
ILP	Lamp
B	Battery
M	Meter
TP	Terminal Post
LK	Link
X	Other Components

Component Composition	
A	Capacitor Polystyrene Tubular
B	Capacitor Polyester Tubular Metalised
C	Capacitor Polyester Tubular Foil
D	Capacitor Paper Foil
E	Capacitor Paper Metalised
F	Capacitor Ceramic Tubular
G	Capacitor Ceramic Disc
H	Capacitor Silver Mica
J	Capacitor Electrolytic Al.
K	Capacitor Electrolytic Al. Plain Foil
L	Capacitor Electrolytic Tantalum
M	Capacitor Variable Air Preset
N	Capacitor Variable Ceramic Disc Preset
P	Capacitor Variable Tubular Preset
R	Capacitor Variable Mica Compression Preset
S	Capacitor Polyester Special
T	Capacitor Polycarbon
V	Resistor Metalised Film
W	Resistor Composition <5%
X	Resistor Composition >5%
Y	Resistor Wire Wound
Z	Resistor Oxide Film >5%

Units and Values			
A	Amp	G	Giga [10^9]
F	Farad	M	Mega [10^6]
H	Henry	k	kilo [10^3]
Ω	Ohm	m	milli [10^{-3}]
V	Volts	μ	micro [10^{-6}]
W	Watts	p	pico [10^{-12}]

Component Parts List for 1604 General Assembly

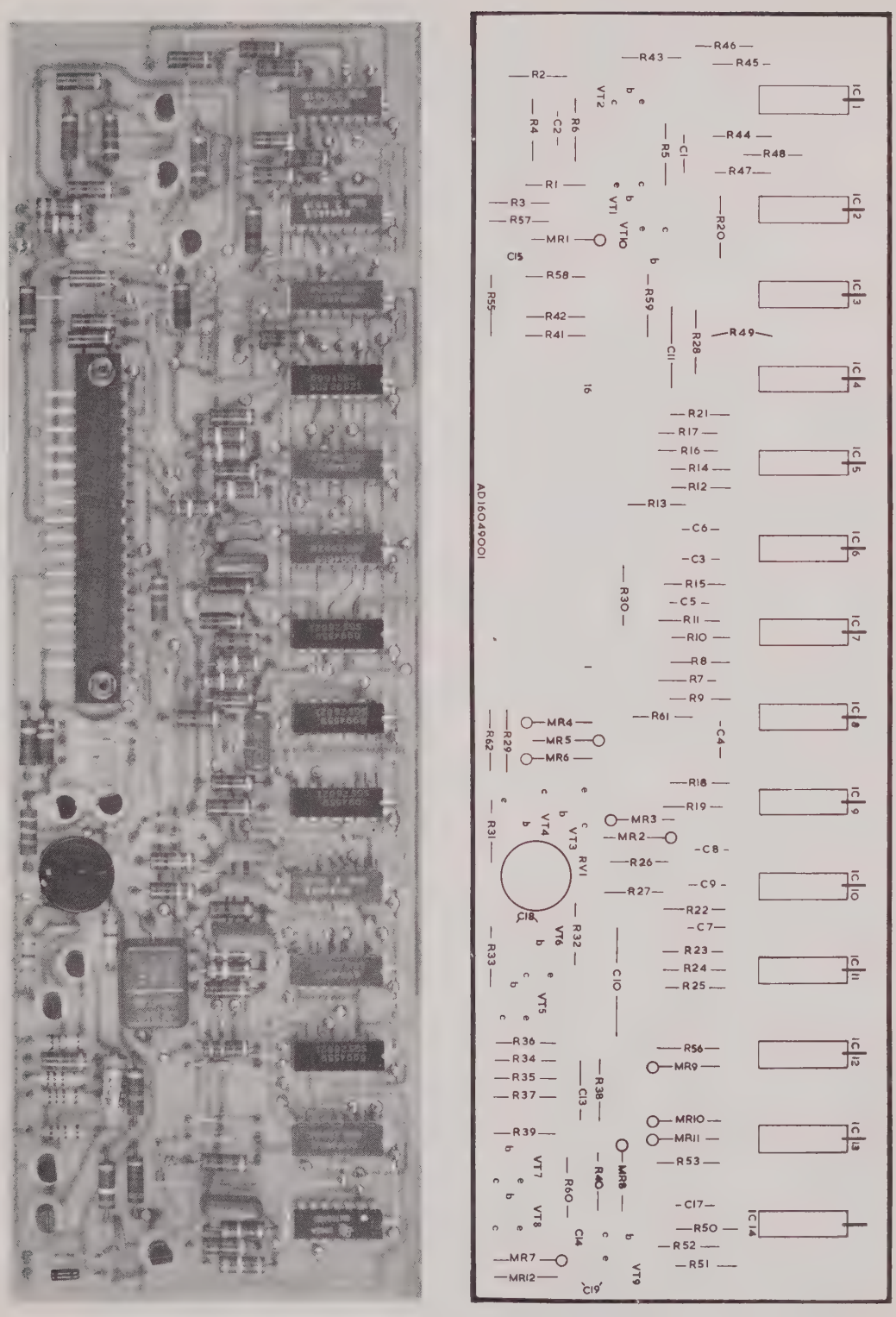
Cct. Ref.	General Description			Solartron Part No.
RV1	500	1W	5%	B16040053
RV2	50K	1W	5%	B16040054
C1	2500	50V	-20% +100%	271192500
PLD	Conn. Plug 18 Way			352318090
RLA to RLD	Reed Relay			300651550
RLE	Reed Relay			300651640
RLF	Reed Relay			300651550
RLG	Reed Relay			300651650
SKT3	Conn. Skt. 8 Way			352518090
S1	Switch Push Button			B16040008
S2	Switch Push Button			B16040010
S3	Switch Push Button			B16040010
S4	Switch Push Button			B16040010
S5	Switch Push Button			B16040011
S6	Switch Push Button			B16040011
T1	Transformer			B16040027
TP1	Conn. Term. Ins. Red			355000770
TP2	Conn. Term. Ins. Black			355000750
TP3	Conn. Term. Ins. Green			355000760
	Guard Link			A16200102
	Screening Board			C16040092
	Cell D-845-D			310010010
VT1	Transistor 2N3054			300552060



Component Parts List for Printed Circuit Board 16049001

Cct. Ref.		General Description			Solartron Part No.
R1	X	1000	½W	10%	172331000
R2	X	1000	½W	10%	172331000
R3	X	4700	½W	10%	172334700
R4	X	2200	½W	10%	172332200
R5	X	4700	½W	10%	172334700
R6	X	4700	½W	10%	172334700
R7	X	3900	½W	10%	172333900
R8	X	3900	½W	10%	172333900
R9 to R11	X	1000	½W	10%	172331000
R12	X	3900	½W	10%	172333900
R13	X	3900	½W	10%	172333900
R14	X	1000	½W	10%	172331000
R15	X	1000	½W	10%	172331000
R16	X	3900	½W	10%	172333900
R17	X	3900	½W	10%	172333900
R18 to R22	X	1000	½W	10%	172331000
R23	X	3900	½W	10%	172333900
R24	X	3900	½W	10%	172333900
R25	X	1000	½W	10%	172331000
R26	X	10K	½W	10%	172341000
R27	X	10K	½W	10%	172341000
R28	X	3900	½W	10%	172333900
R29	X	12K	½W	10%	172341200
R30	X	68K	½W	10%	172346800
R31	X	56K	½W	10%	172345600
R32	Z	3900	½W	5%	193533900
R33	Z	3900	½W	5%	193533900
R34	X	1800	½W	10%	172331800
R35	Z	1000	½W	1%	195431000
R36	Z	2200	½W	1%	195432200
R37	Z	2700	½W	1%	195432700
R38	X	2700	½W	10%	172332700
R39	Z	2200	½W	1%	195432200
R40	X	8200	½W	10%	172338200
R41 to R49	X	1000	½W	10%	172331000
R50	X	3900	½W	10%	172333900
R51	X	3900	½W	10%	172333900
R52	X	1000	½W	10%	172331000
R53	X	1000	½W	10%	172331000
R55	X	4700	½W	10%	172334700
R56	X	3300	½W	10%	172333300
R57	X	39K	½W	10%	172343900
R58	X	2200	½W	10%	172332200
R59	X	1000	½W	10%	172331000
R60	X	3900	½W	10%	172333900
R61	X	1000	½W	10%	172331000
R62	X	220	½W	10%	172322200

RV1	Res. Var. Comp.				136631000
C1	F	100p	500V	10%	208400044
C2	F	100p	500V	10%	208400044
C3	B	.033	250V	10%	225743300
C4	C	.01	100V	10%	227041000
C5	F	1000p	500V	20%	208400048
C6	F	1000p	500V	20%	208400048
C7	C	.022	100V	10%	227042200
C8	F	2200p	500V	20%	208400083
C9	F	2200p	500V	20%	208400083
C10		2.2	63V	20%	219962200
C11		470p	160V	10%	221324700
C12	C	470p	160V	10%	221324700
C13	A	270p	630V	1%	210322700
C13	A	220p	630V	1%	210322200
	[for 60Hz operation only]				
C14	G	.01	25V	-25% +50%	241941000
C15	G	.047	25V	-25% +50%	241944700
C17	C	.01	100V	10%	227041000
C18	G	.047	25V	-25% +50%	241944700
C19	G	.047	25V	-25% +50%	241944700
C20	C	220p	400	10%	222322200
IC1 to IC3	Integrated Circuit 846				510000160
IC4	Integrated Circuit 845				510000150
IC5	Integrated Circuit 846				510000160
IC6	Integrated Circuit 846				510000160
IC7 to IC9	Integrated Circuit 845				510000150
IC10	Integrated Circuit 846				510000160
IC11	Integrated Circuit 846				510000160
IC12	Integrated Circuit 845				510000150
IC13	Integrated Circuit 846				510000160
IC14	Integrated Circuit 845				510000150
MR1 to MR11	SD3	Solartron			300422160
MR12	SZD13				300523920
VT1	D2039/D1501				300553421
VT2	D2039/D1501				300553421
VT3	D1562/D1501				300552961
VT4	D1562/D1501				300552961
VT5	D1563/D1501				300553031
VT6	D2039/D1501				300553421
VT8	D2039/D1501				300553421
VT9	D2039/D1501				300553421
VT10	D2039/D1501				300553421
VT7	D1561/1501				300552991



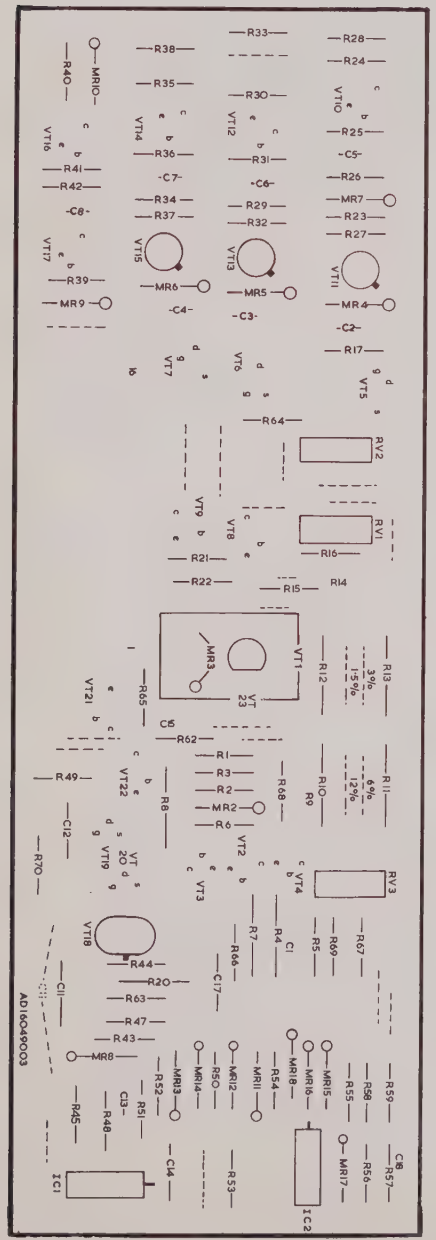
Component Location - Board 1

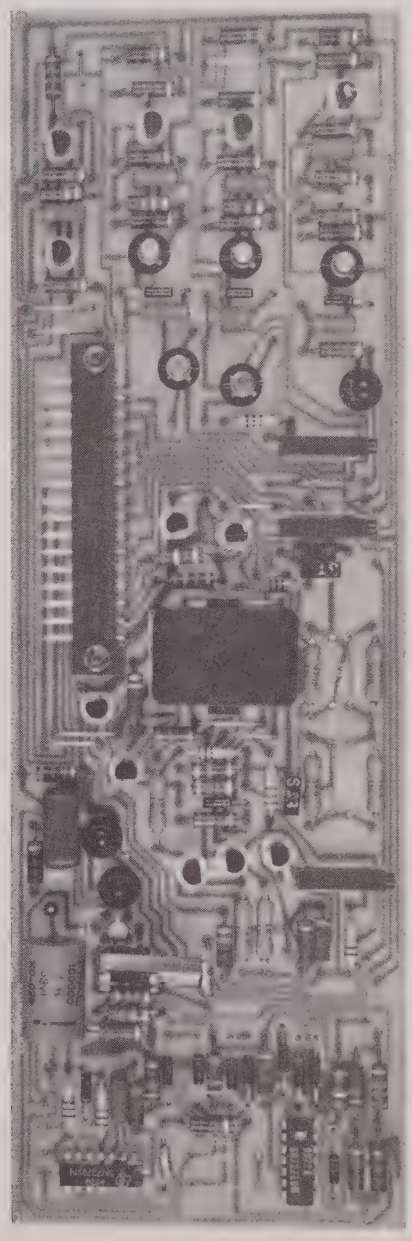
Component Parts List for Printed Circuit Board 16049003

Cct. Ref.	General Description				Solartron Part No.
R1	Z	10	½W	5%	193511000
R2	X	4700	½W	10%	172334700
R3	X	470	½W	10%	172324700
R4	V	1200	½W	1%	198331204
R5	X	1500	½W	10%	172331500
R6	X	6800	½W	10%	172336800
R7	V	3900	½W	1%	198333904
R8	V	3900	½W	1%	198333904
R9	V	27K	0.4W	To Spec	B16040001
R10	V	3000	½W	1%	198333004
R11	V	1500	½W	1%	198331504
R12	V	390	½W	1%	198323904
R13	V	750	½W	1%	198327504
R14	V	10K	0.4W	To Spec	B16040001
R15	Z	10	½W	5%	193511000
R16	X	100K	½W	10%	172351000
R17	X	22M	½W	10%	172372200
R20	V	82K	1.2W	1%	B16040003
R21	X	3900	½W	10%	172333900
R22	X	33K	½W	10%	172343300
R23	X	18K	½W	10%	172341800
R24	X	2200	½W	10%	172332200
R25	X	1000	½W	10%	172331000
R26	X	1000	½W	10%	172331000
R27	X	1000	½W	10%	172331000
R28	X	10K	½W	10%	172341000
R29	X	18K	½W	10%	172341800
R30	X	2200	½W	10%	172332200
R31	X	1000	½W	10%	172331000
R32	X	1000	½W	10%	172331000
R33	X	10K	½W	10%	172341000
R34	X	18K	½W	10%	172341800
R35	X	2200	½W	10%	172332200
R36	X	1000	½W	10%	172331000
R37	X	1000	½W	10%	172331000
R38	X	10K	½W	10%	172341000
R39	X	2200	½W	10%	172332200
R40	X	47K	½W	10%	172344700
R41	X	1000	½W	10%	172331000
R42	X	10K	½W	10%	172341000
R43	X	2200	½W	10%	172332200
R44	W	4700	1/8W	5%	170234700
R45	Z	1000	½W	5%	193531000
R47	X	56K	½W	10%	172345600
R48	Z	1000	½W	5%	193531000
R49	X	47K	½W	10%	172344700
R50	X	470	½W	10%	172324700
R51	X	1500	½W	10%	172331500
R52	X	470	½W	10%	172324700
R53	X	2200	½W	10%	172332200
R54	X	1500	½W	10%	172331500
R55	X	390	½W	10%	172323900
R56	X	1000	½W	10%	172331000
R57	X	1000	½W	10%	172331000
R58	X	15K	½W	10%	172341500
R59	X	33K	½W	10%	172343300
R62	X	3300	½W	10%	172333300
R63	X	47K	½W	10%	172344700
R64	Z	100	½W	5%	193521000
R65	X	220K	½W	10%	172352200
R66	X	10K	½W	10%	172341000
R67	Z	12K	½W	5%	193541200
R68	Z	560	½W	5%	193525600
R69	X	2200	½W	10%	172332200
R70	X	10	½W	10%	172311000
RV1		20K	½W	10%	121242000
RV2		200	½W	10%	121222000
RV3		10K	½W	10%	121241000
C1	G	0.047	25V	-25% +50%	241944700
C2 to C8	F	33p	750V	10%	240413300
C11	A	0.1	63V	10%	208100139
C12	B	1.5	63V	10%	225161500
C13	C	4700p	100V	10%	227034700
C14	A	220p	125V	10%	210222200
C15	B	0.047	25V	-25% +50%	241944700
C17	A	10p	125V	10%	210211000
C18	G	0.047	25V	-25% +50%	241944700
IC1		I.C. OP. AMP μA727091			510000250
IC2		I.C. Comparator SN72710N			510000240
MR2		SZD5.6	Solartron		300521450
MR3		IN937			B16040105
MR4 to MR6		IN3595			300523590
MR7		SD3	Solartron		300522160
MR8		SZD6.8	Solartron		300522540
MR9		SD3	Solartron		300522160
MR10		SD3	Solartron		300522160
MR11		SZD7.5	Solartron		300521460
MR12		SZD7.5	Solartron		300521460
MR13		SZD7.5	Solartron		300521460
MR14		SZD7.5	Solartron		300521460
MR15		SZD4.3	Solartron		300523900
MR16		SZD4.3	Solartron		300523900
MR17		SZD2	Solartron		300521480
MR18		SZD6.2	Solartron		300521240
VT1		40514			300553790

Cct. Ref.	General Description	Solartron Part No.
VT2	D1563/D1501	300553031
VT3	D1563/D1501	300553031
VT4	D1562/D1501	300552861
VT5 to VT7	U1897E	300553800
VT8	D1561/D1501	300552991
VT9	BC183L/D1501	300553321
VT10	D2039/D1501	300553421
VT11	BCY70	300553590
VT12	D2039/D1501	300553421
VT13	BCY70	300553590

Cct. Ref.	General Description	Solartron Part No.
VT14	D2039/D1501	300553421
VT15	BCY70	300553590
VT16	D1561/D1501	300552991
VT17	BC1831/D1501	300553321
VT18	2N3958	300553810
VT19	2N4303	300553160
VT20	2N4303	300553160
VT21	D2039/D1501	300553421
VT22	D1563/D1501	300553031
VT23	D1561/D1501	300552991
	Conn. P.C.B. 16 Way	352316060
	Ferrite Bead FX1242 Qty 2.	309010010





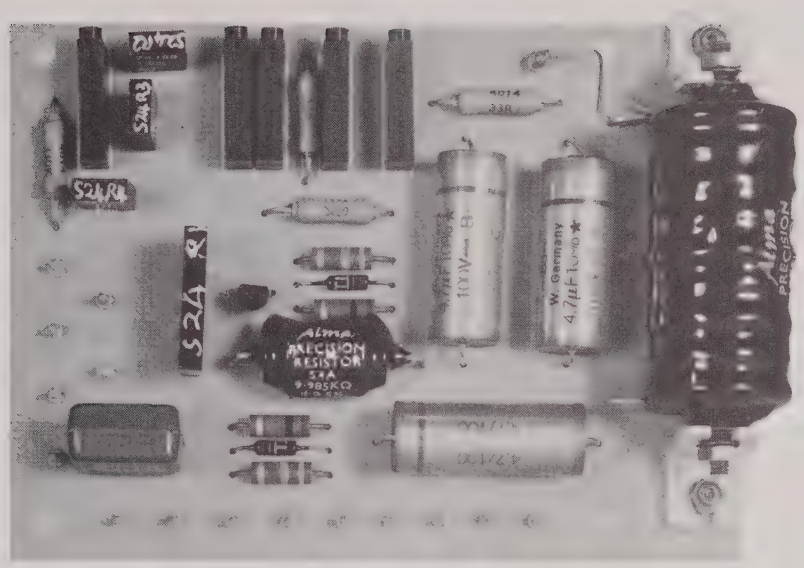
Component Location - Board 3

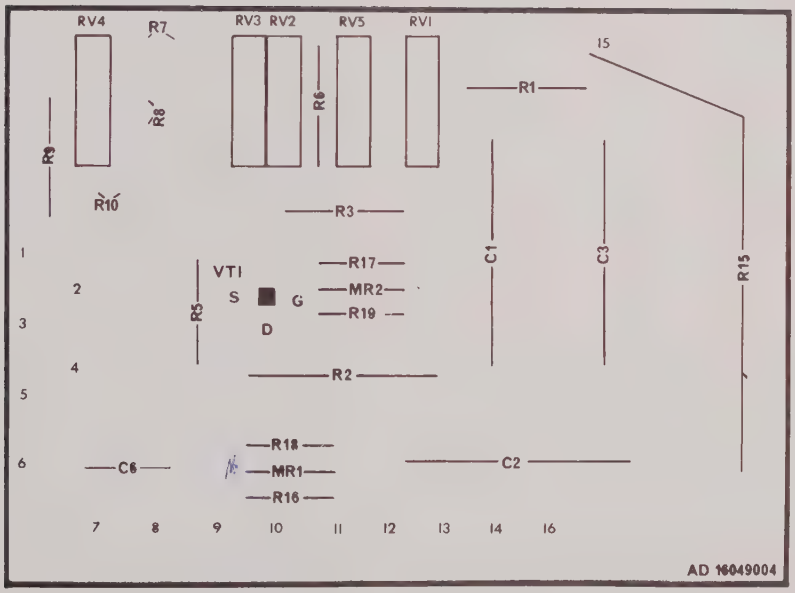
Component Parts List
for
Printed Circuit Board 16049004

Cct. Ref.		General Description			Solartron Part No.
R1	V	33	½W	1%	198313302
R2		9985	¼W	To Spec	
R3	W	68K	¼W	1%	170456800
R5	V	71.89K	¼W	1%	B16040002
R6	V	22	½W	1%	198312202
R7	V	7188	¼W	1%	B16040002
R8	V	722.7	¼W	1%	B16040002
R9	V	330K	½W	1%	198353302
R10	V	80	¼W	1%	B16040002
R16	X	4700	½W	10%	172334700
R17	X	4700	½W	10%	172334700
R18	X	1M	½W	10%	172361000
R19	X	1M	½W	10%	172361000
RV1 to RV4		1000	½W	10%	121231000
RV5		200	½W	10%	121222000
C1 to C3	B	4.7	100V	10%	219864700
C6	B	1.0	100V	10%	225461000
MR1		IS134			300522430
MR2		IS134			300522430
VT1		TIXS78			300553820
R15		9.99M	1W	To Spec	B16040025

(EMI Type [illegible] 84) 25614-130-091

25614-130-068

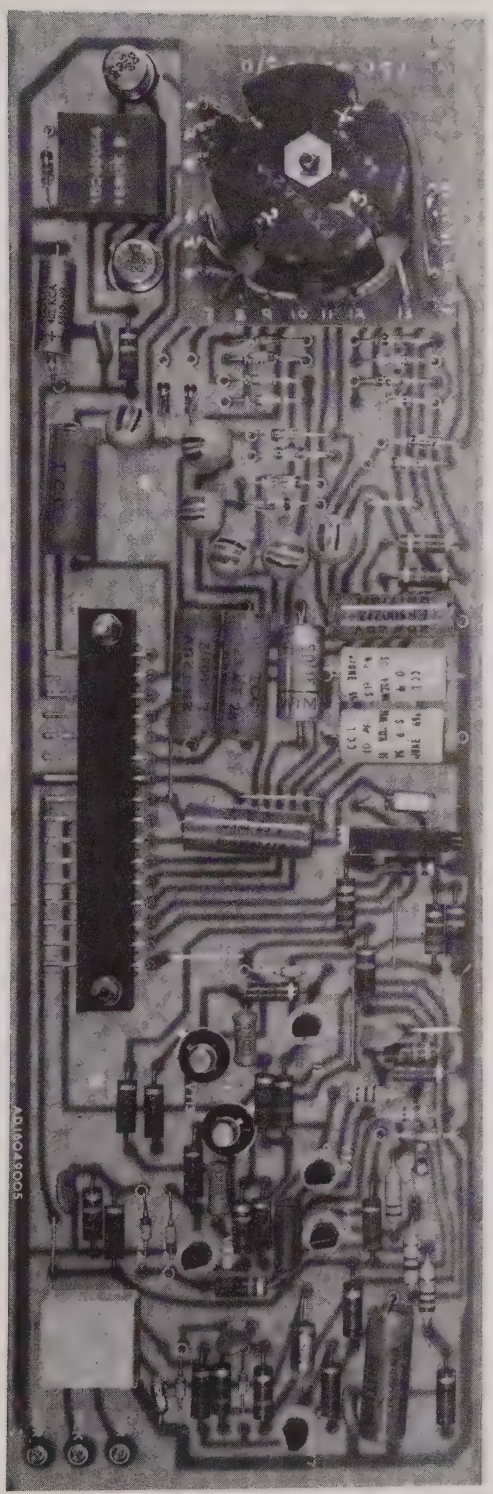


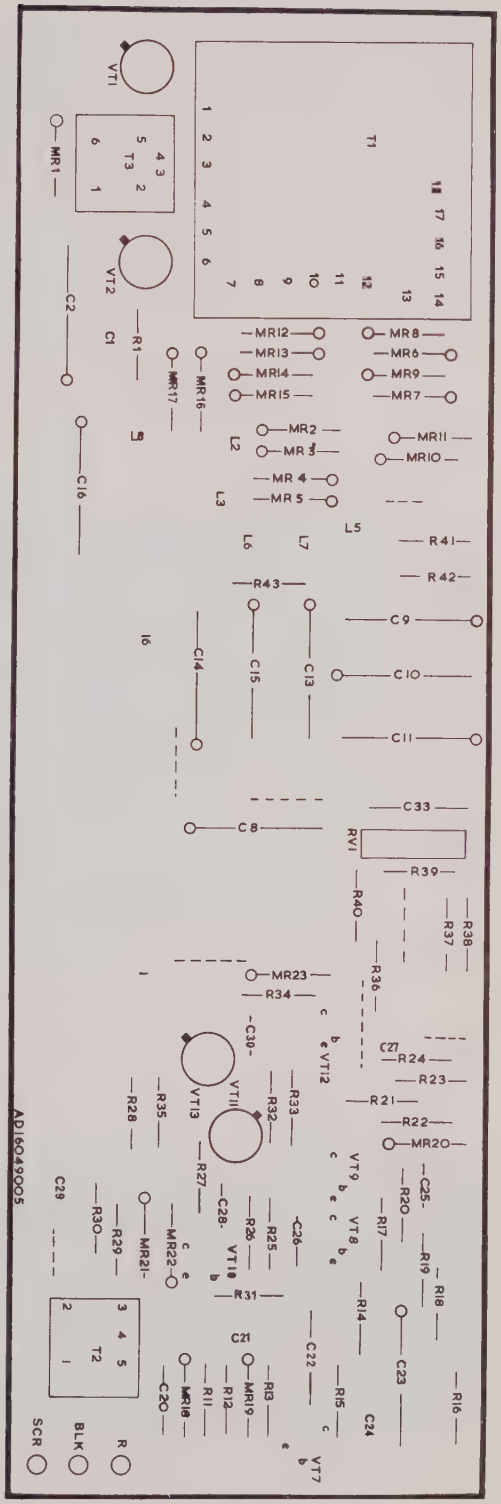


Component Location - Board 4

Component Parts List for Printed Circuit Board 16049005

Cct. Ref.		General Description			Solartron Part No.
R11	X	150	½W	10%	172321500
R12	X	5600	½W	10%	172335600
R13	X	5600	½W	10%	172335600
R14	X	1500	½W	10%	172331500
R15	X	2200	½W	10%	172332200
R16	X	15	½W	10%	172311500
R18	Z	1600	½W	5%	193531600
R19	Z	4700	½W	5%	193534700
R20	Z	10K	½W	5%	193541000
R21	Z	2700	½W	5%	193532700
R22	Z	4300	½W	5%	193534300
R23	X	2200	½W	10%	172332200
R24	X	18K	½W	10%	172341800
R25	X	100	½W	10%	172321000
R26	X	10K	½W	10%	172341000
R27	X	1000	½W	10%	172331000
R28	X	1000	½W	10%	172331000
R29	X	2200	½W	10%	172332200
R30	X	10K	½W	10%	172341000
R31	X	10K	½W	10%	172341000
R32	X	100	½W	10%	172321000
R33	X	6800	½W	10%	172336800
R34	X	1000	½W	10%	172331000
R35	X	1000	½W	10%	172331000
R36	X	10K	½W	10%	172341000
R37	X	82K	½W	10%	172348200
R38	X	10K	½W	10%	172341000
R39	X	10K	½W	10%	172341000
R40	X	82K	½W	10%	172348200
R41	X	270	½W	10%	172322700
R42	X	270	½W	10%	172322700
R43	X	47K	½W	10%	172344700
RV1		20K	½W	10%	121242000
C1	G	0.047	25V	-25% +50%	241944700
C2	L	10	35V	10%	265971000
C8	J	25	25V	-20% +100%	270772500
C9	J	25	25V	-20% +100%	270772500
C10	J	10	50V	-20% +100%	271071000
C11	J	10	50V	-20% +100%	271071000
C13	J	50	12V	-20% +100%	270475000
C14	J	25	25V	-20% +100%	270772500
C15	J	25	25V	-20% +100%	270772500
C16	J	25	25V	-20% +100%	270772500
C21	G	.01	25V	-25% +50%	241941000
C22	A	1000p	125V	10%	210231000
C23	J	25	25V	-20% +100%	270772500
C24	G	0.047	25V	-25% +50%	241944700
C25	F	47p	200V	10%	240714700
C26	B	.068	100V	10%	225446800
C27	G	0.047	25V	-25% +50%	241944700
C28	F	150p	500V	10%	208400045
C29	G	0.047	25V	-25% +50%	241944700
C30	F	150p	500V	10%	208400045
C33	A	680p	125V	10%	210226800
C20	A	100p	125V	10%	210221000
MR1 to MR11		BAY 72			300524530
MR12 to MR15		SD3			300522160
MR16		BAY 72			300524530
MR17		BAY 72			300524530
MR18 to MR23		SD3			300522160
VT1		BFY50			300553610
VT2		BFY50			300553610
VT7		D2039/D1501			300553421
VT8		BC183L			300553321
VT9		BC183L			300553321
VT10		D1561/D1501			300552991
VT11		BC107/S			300553320
VT12		D1561/D1501			300552991
VT13		BC107/S			300553320
T1		Transformer			B16040026
T2		Transformer			A14900060
T3		Transformer			B16040044
L2		Choke R.F. 56μH			305020360
L3		Choke R.F. 56μH			305020360
L5		Choke R.F. 56μH			305020360
L6		Choke R.F. 56μH			305020360
L7		Choke R.F. 56μH			305020360
L8		Choke R.F. 56μH			305020360
		Connector Plug 16 Way			352316060

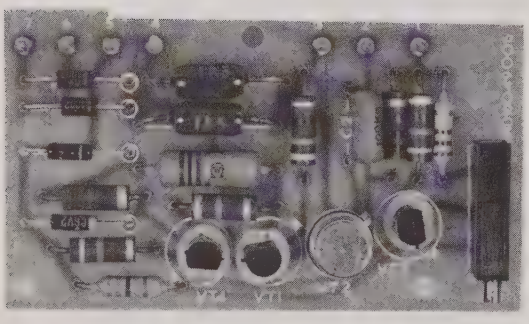


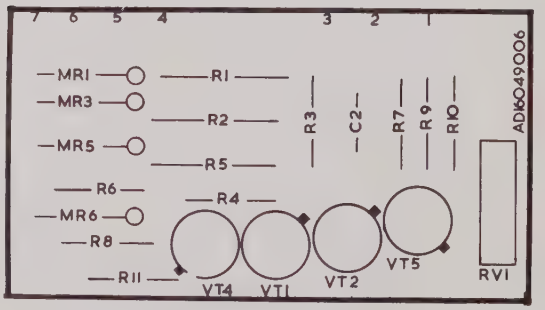


Component Location – Board 5

Component Parts List
for
Printed Circuit Board 16049006

Cct. Ref.	General Description				Solartron Part No.
R1	Y	1.5	2.6W	5%	173401500
R2	Y	1.5	2.6W	5%	173401500
R3	X	470	½	10%	172324700
R4	X	4700	½	10%	172334700
R5	Z	1000	1W	5%	193431000
R6	X	1500	½W	10%	172331500
R7	X	1000	½W	10%	172331000
R8	X	4700	½W	10%	172334700
R9	X	4700	½W	10%	172334700
R10	Z	8200	½W	5%	193538200
R11	Z	3300	½W	5%	193533300
RV1		1000	½W	10%	121231000
C2	F	100p	500V	10%	208400044
MR1		IN4002			300522510
MR3		IN4002			300522510
MR5		SZD12	Solartron		300521480
MR6		SZD6.2	Solartron		300521240
VT1		D1561/D1501			300552991
VT2		2N4037	Texas		300553170
VT4		D1562/D1501			300552861
VT5		D1562/D1501			300552861

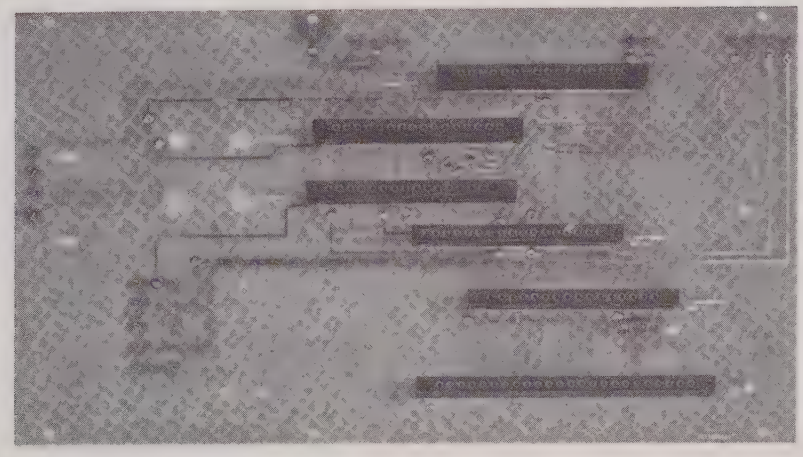


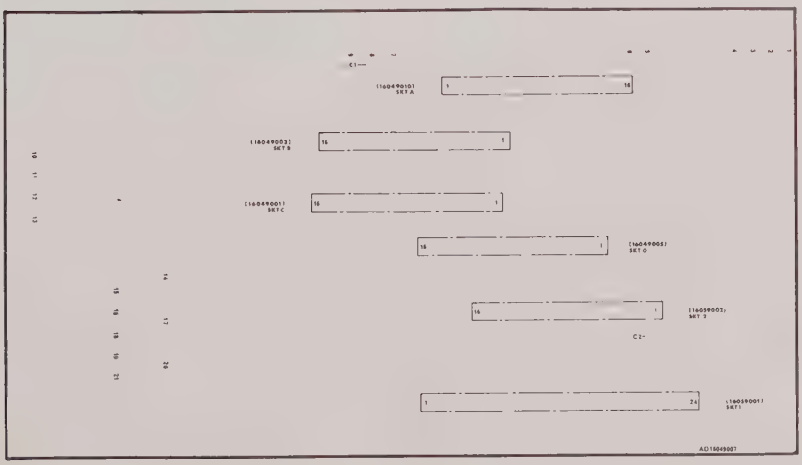


Component Location - Board 6

Component Parts List
for
Printed Circuit Board 16049007

Cct. Ref.		General Description			Solartron Part No.
C1	C	.001	400V	10%	222331000
C2	F	0.1	30V	-25% +50%	242051000
SKTA to SKTD		Con. Skt. Fixed 16 Way			352516170
SKT1		Con. Skt. Fixed 24 Way			352524120
SKT2		Con. Skt. Fixed 16 Way			352516170

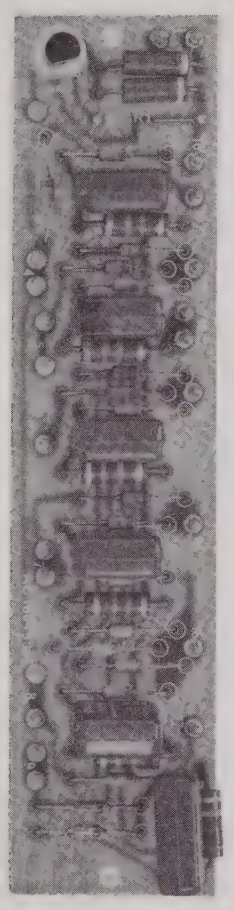


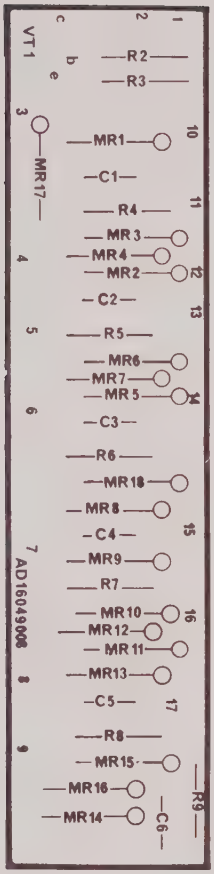


Component Location - Board 7

Component Parts List
for
Printed Circuit Board 16049008

Cct. Ref.	General Description				Solartron Part No.
R2	X	2200	½	10%	172332200
R3	X	2200	½	10%	172332200
R4 to R8	X	47K	½W	10%	172344700
R9	X	22K	½W	10%	172342200
C1 to C5	B	0.22	100V	10%	225452200
C6	B	0.47	100V	10%	225454700
MR1 to MR18		SD3	Solartron		300522160
VT1		D2039/D1501			300553421





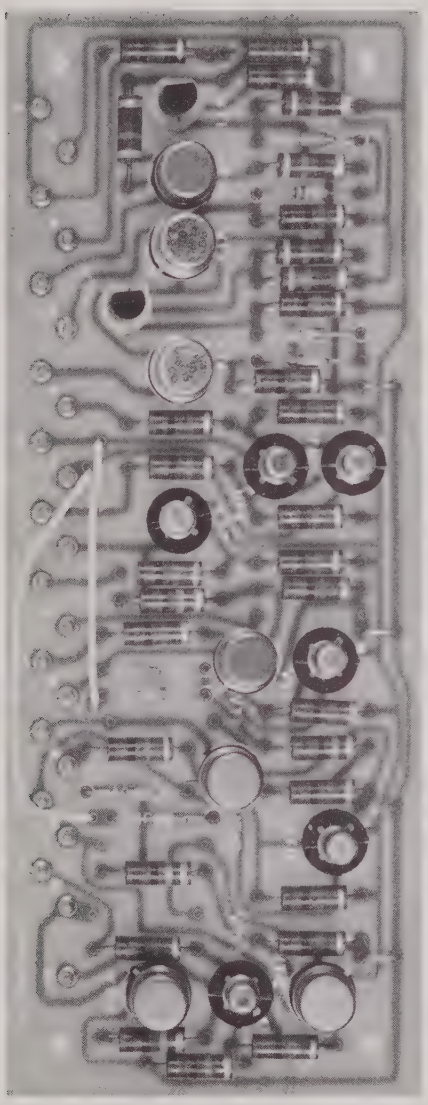
Component Location - Board 8

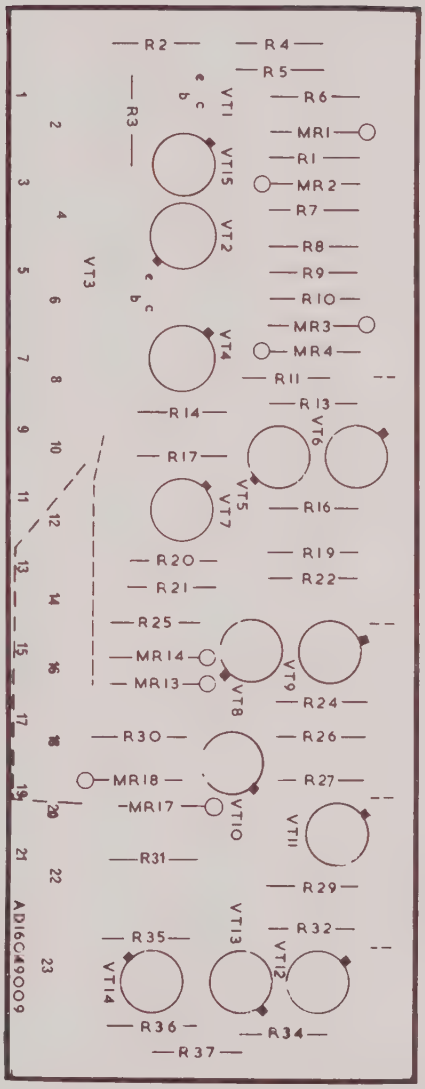
Component Parts List for Printed Circuit Board 16049009

Cct. Ref.	General Description				Solartron Part No.
R1	X	470	½W	10%	172324700
R2	X	1000	½W	10%	172331000
R3	X	470	½W	10%	172324700
R4	X	2200	½W	10%	172332200
R5	X	1000	½W	10%	172331000
R6	X	470	½W	10%	172324700
R7	X	1000	½W	10%	172331000
R8	X	470	½W	10%	172324700
R9	X	470	½W	10%	172324700
R10	X	1000	½W	10%	172331000
R11	X	1000	½W	10%	172331000
R13	X	1000	½W	10%	172331000
R14	X	1000	½W	10%	172331000
R16	X	1000	½W	10%	172331000
R17	X	1000	½W	10%	172331000
R19	X	1000	½W	10%	172331000
R20	X	1000	½W	10%	172331000
R21	X	10K	½W	10%	172341000
R22	X	1000	½W	10%	172331000
R24	X	1000	½W	10%	172331000
R25	X	1000	½W	10%	172331000
R26	X	10K	½W	10%	172341000
R27	X	1000	½W	10%	172331000
R29	X	1000	½W	10%	172331000
R30	X	1000	½W	10%	172331000
R31	X	10K	½W	10%	172341000
R32	X	1000	½W	10%	172331000
R34	X	1000	½W	10%	172331000
R35	X	1000	½W	10%	172331000
R36	X	10K	½W	10%	172341000
R37	X	1000	½W	10%	172331000

MR1 to MR4	SD3	Solartron	300522160
MR13	SD3	Solartron	300522160
MR14	SD3	Solartron	300522160
MR17	SD3	Solartron	300522160
MR18	SD3	Solartron	300522160

VT1	D2039/D1501	300553421
VT2	BFY50	300553610
VT3	D2039/D1501	300553421
VT4	BFY50	300553610
VT5 to VT7	BCY70	300553590
VT8	A1778/2	300551430
VT9	BCY70	300553590
VT10	A1778/2	300551430
VT11	BCY70	300553390
VT12	A1778/2	300551430
VT13	BCY70	300553390
VT14	A1778/2	300551430
VT15	A1778/2	300551430





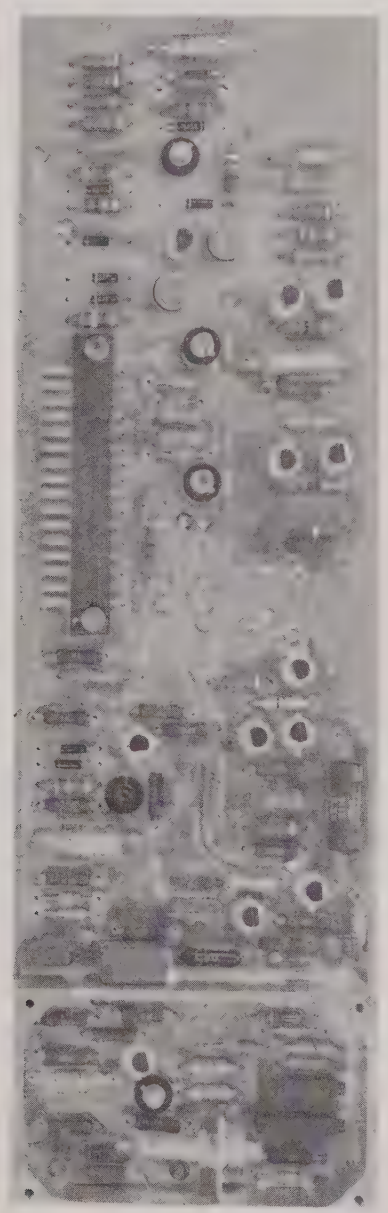
Component Location - Board 9

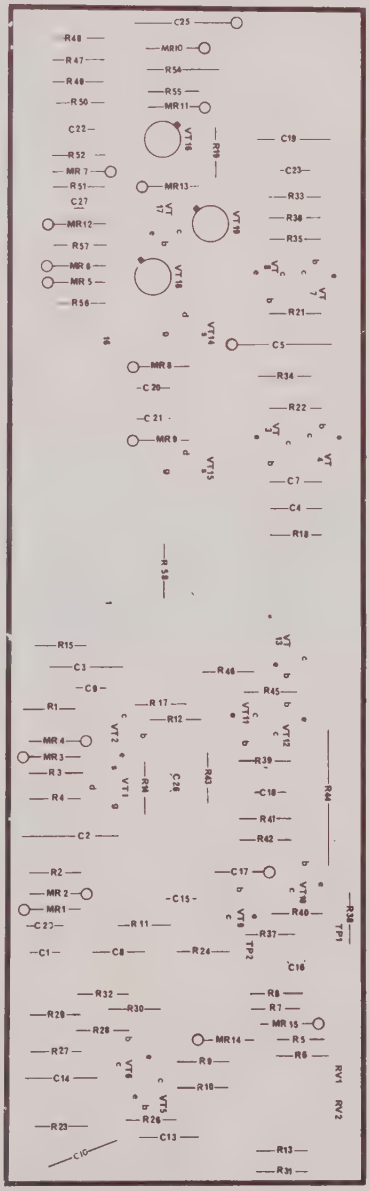
Component Parts List for Printed Circuit Board 16049010

Cct. Ref.		General Description			Solartron Part No.
R1	W	1000	1/8W	5%	170231000
R2	W	10K	1/8W	5%	170241000
R3	X	4700	½W	10%	172334700
R4	W	470K	1/8W	5%	170254700
R5	Z	3300	½W	5%	193533300
R6	Z	7500	½W	5%	193537500
R7	Z	470	½W	5%	193524700
R8	Z	4300	½W	5%	193534300
R9	Z	620	½W	5%	193526200
R10	Z	9100	½W	5%	193539100
R11	W	10K	1/8W	5%	170241000
R12	W	10K	1/8W	5%	170241000
R13	W	10K	1/8W	5%	170241000
R14	W	560	1/8W	5%	170225600
R15	W	1000	1/8W	5%	170231000
R17	W	10K	1/8W	5%	170241000
R18	W	100K	1/8W	5%	170251000
R19	X	10K	½W	10%	172341000
R21	X	1000	½W	10%	172331000
R22	W	2200	1/8W	5%	170232200
R23	W	47K	1/8W	5%	170244700
R24	W	2200	1/8W	5%	170232200
R26	W	10	1/8W	5%	170211000
R27	W	100K	1/8W	5%	170251000
R28	W	47K	1/8W	5%	170244700
R29	W	470	1/8W	5%	170224700
R30	W	3300	1/8W	5%	170233300
R31	Z	680K	½W	5%	193556800
R32	W	10K	1/8W	5%	170241000
R33	X	2200	½W	10%	172332200
R34	W	220K	1/8W	5%	170252200
R35	X	47K	½W	10%	172344700
R36	X	3300	½W	10%	172333300
R37	W	22K	1/8W	5%	170242200
R38	Z	680K	½W	5%	193556800
R39	W	22K	1/8W	5%	170242200
R40	W	1000	1/8W	5%	170231000
R41	X	2200	½W	10%	172332200
R42	W	82K	1/8W	5%	170248200
R43	W	33K	1/8W	5%	170243300
R44	W	22M	1W	5%	171472200
R45	Z	100	½W	5%	193521000
R46	X	1200	½W	10%	172331200
R47	X	1200	½W	10%	172331200
R48	X	2200	½W	10%	172332200
R49	X	2200	½W	10%	172332200
R50	X	22K	½W	10%	172342200
R51	X	10K	½W	10%	172341000
R52	X	470	½W	10%	172324700
R54	X	470	½W	10%	172324700
R55	X	1000	½W	10%	172331000
R56	X	390	½W	10%	172323900
R57	X	1000	½W	10%	172331000
R58	X	33K	.25W	10%	172343300
RV1		200	½W	10%	121222000
RV2		2000	½W	10%	121232000
C1	B	.022	100V	10%	225442200
C2	B	0.22	160V	10%	220352200
C3	B	680p	160V	10%	221326800
C4	B	1.0	100V	10%	225461000
C5	L	100	10V	10%	265381000
C7	F	100p	750V	10%	240421000
C8	B	1.0	100V	10%	225461000
C9	F	1000p	500V	20%	208400048
C10	H	56p	350V	5%	208500045
C13	P	3-30p			290060050
C14	C	.047	160V	10%	220344700
C15	C	.01	100V	10%	227041000
C16	G	.047	25V	+50% -25%	241944700
C17	L	10	20V	20%	208700035
C18	F	68p	750V	10%	240416800
C19	C	3300p	160V	10%	221333300
C20	F	33p	750V	10%	240413300
C21	F	33p	750V	10%	240413300
C22	F	33p	750V	10%	240413300
C23	F	22p	750V	10%	240412200
C25	J	25	12V	-20% +100%	270472500
C26	G	.047	25V	+50% -25%	241944700
C27	G	.047	25V	+50% -25%	241944700
C28		82p	500V	20%	208400038

MR1	SD3	Solartron	300522160
MR2	SD3	Solartron	300522160
MR3	IN3595	Motorola	300523590
MR4	IN3595	Motorola	300523590
MR5	IN3595	Motorola	300523590
MR6	IN3595	Motorola	300523590
MR7	SZD3.3	Solartron	300521860
MR8	SD3	Solartron	300522160
MR9	SD3	Solartron	300522160
MR10	SZD7.5	Solartron	300521460
MR11	SZD7.5	Solartron	300521460
MR12	SZD9.1	Solartron	300521340
MR13	SZD3.3	Solartron	300521860
MR14	SD3	Solartron	300522160
MR15	SD3	Solartron	300522160
VT1	2N4303	Texas	300553160
VT2	D1563/D1501		300553031
VT3	D1562/D1501		300552861
VT4	D1563/D1501		300553031
VT5	2N2484	Texas	300552860
VT6	D1563/D1501		300553031

Cct. Ref.	General Description	Solartron Part No.	Cct. Ref.	General Description	Solartron Part No.
VT7	D1563/D1501	300553031	VT15	U1897E	300553800
VT8	D2039/D1501	300553421	VT16	BC107/S Mullard	300553320
VT9	D1563/D1501	300553031	VT17	D1561/D1501	300552991
VT10	D1562/D1501	300552861	VT18	A1778/2	300551430
VT11	D1563/D1501	300553031	VT19	2N4036	300553060
VT12	D1561/D1501	300552991			
VT13	BC183L/D1501	300553321			
VT14	U1897E	300553800		Conn. Plug 16 Way	352316060

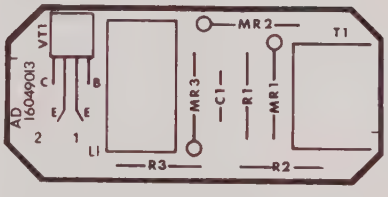




Component Location - Board 10

Component Parts List
for
Printed Circuit Board 16049013

Cct. Ref.	General Description				Solartron Part No.
R1	Z	4700	½W	5%	193534700
R2	Z	4700	½W	5%	193534700
R3	Z	4700	½W	5%	193534700
C1	F	330p	500V	20%	208400100
MR1 to MR3		SD3	Solartron		300522160
VT1		3N88 Transistor			300552180
L.1		Choke			A14900061
T.1		Transformer/Choke			B14900058



Component Location - Board 13

AC CONVERTER

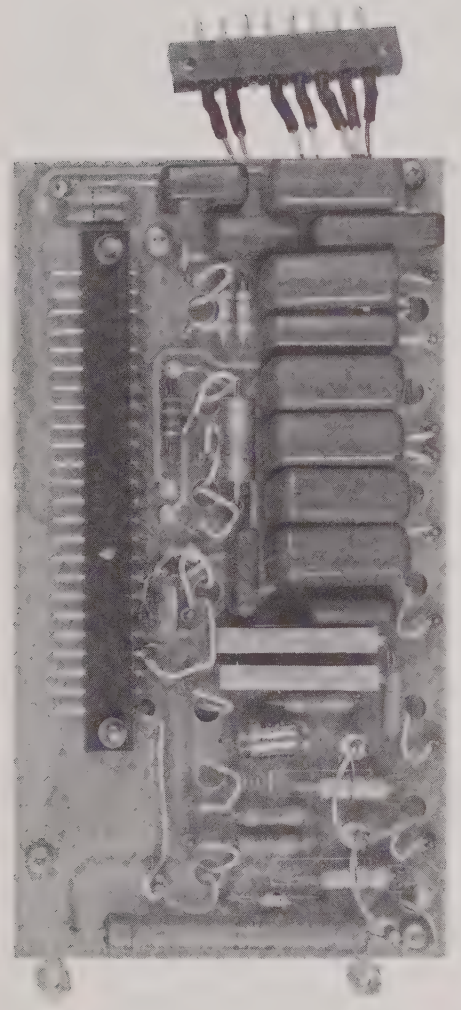
EX1605

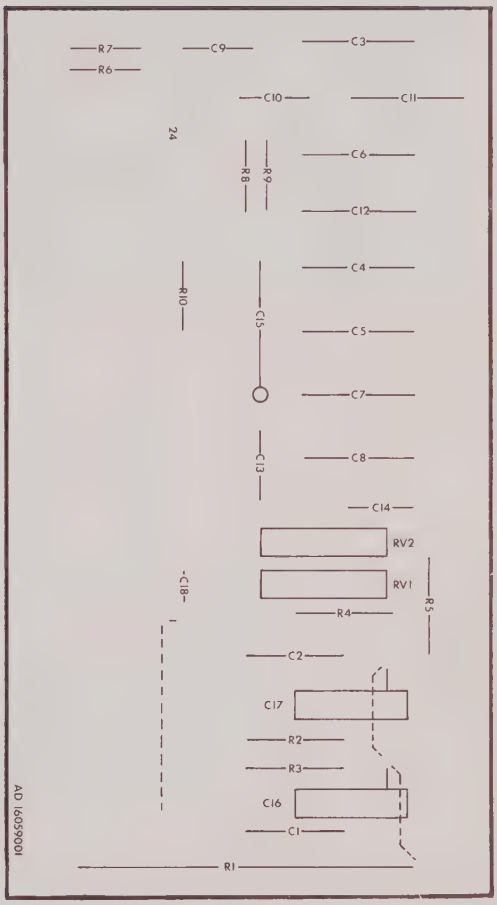
Component Parts List for 1605 General Assembly

Cct. Ref.	General Description	Solartron Part No.
RLA	Relay	300651640
RLB	Relay	300651640
RLC	Relay	300651550
RLD	Relay	300651550
RLE	Relay	300651550
RLF	Relay	300651560
RLG	Relay	300651550
PLA	Conn. Plug fixed 8 Way	352308050

Component Parts List
for
Printed Circuit Board 16059001

Cct. Ref.	General Description				Solartron Part No.
R1	V	990K	2W	0.1%	160400389
R2	V	100K	½W	0.5%	198251001
R3	V	11K	½W	0.1%	198141104
R4	V	9100	½W	0.5%	198239101
R5	V	1100	½W	0.1%	198131104
R6	Z	47K	½W	5%	193544700
R7	Z	47K	½W	5%	193544700
R8	Z	47K	½W	5%	193544700
R9	Z	47K	½W	5%	193544700
R10	X	3300	½W	10%	172333300
RV1		20K	¾W	20%	124042000
RV2		2000	¾W	20%	124032000
C1	A	470p	125V	10%	210224700
C2	A	4700p	125V	10%	210234700
C3 to C8	C	3.3	100V	10%	225463300
C9	C	0.68	100V	10%	225456800
C10	C	0.68	100V	10%	225456800
C11	C	1.5	100V	10%	225461500
C12	C	1.5	100V	10%	225461500
C13	C	0.33	100V	10%	225453300
C14	C	0.33	100V	10%	225453300
C15	L	100	10V	10%	265381000
C16	P	0.7-3p	500V	10%	290030030
C17	P	0.7-3p	500V	10%	290030030
PLA		Conn. Plug. Fixed 24 Way			352324090



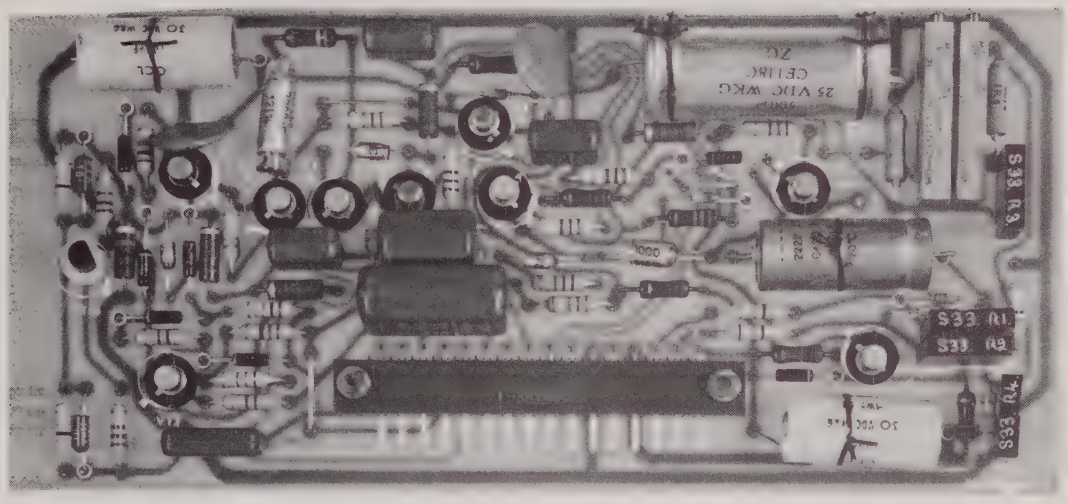


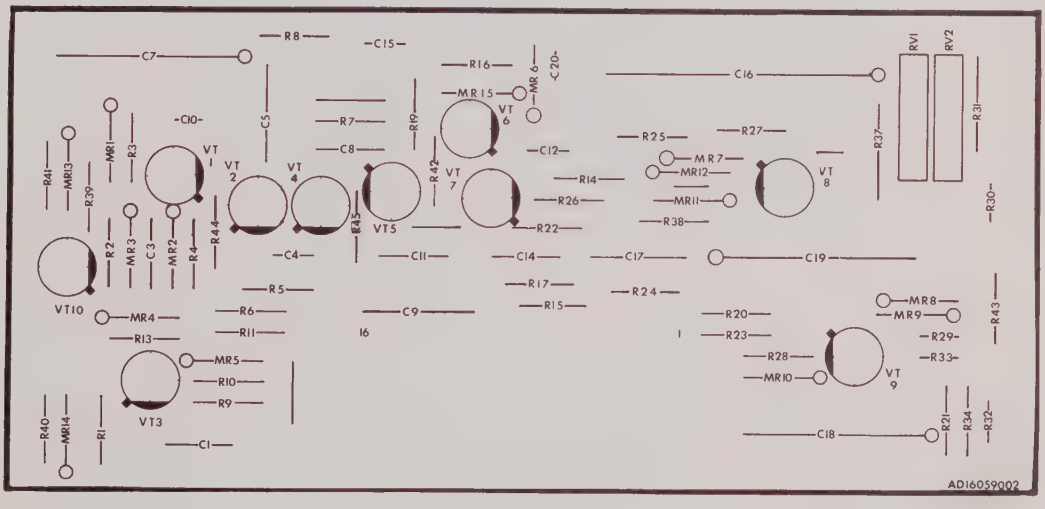
Component Location - Board 1

Component Parts List for Printed Circuit Board 16059002

Cct. Ref.	General Description				Solartron Part No.
R1	Z	2200	½W	5%	193532200
R2	X	10M	½W	10%	172371000
R3	Z	10K	½W	5%	193541000
R4	X	2.2M	½W	10%	172362200
R5	X	2.2M	½W	10%	172362200
R6	Z	10K	½W	5%	193541000
R7	Z	27K	½W	5%	193542700
R8	Z	430	½W	2%	195424300
R9	Z	4700	½W	5%	193534700
R10	Z	150	½W	5%	193521500
R11	Z	150	½W	5%	193521500
R13	Z	4700	½W	5%	193534700
R14	Z	5600	½W	5%	193535600
R15	Z	2200	½W	5%	193532200
R16	Z	1000	½W	5%	193531000
R17	Z	100	½W	5%	193521000
R19	X	2.2M	½W	10%	172362200
R20	Z	47K	½W	1%	195444700
R21	X	3900	½W	5%	193533900
R22	Z	5600	½W	5%	193535600
R23	Z	47K	½W	1%	195444700
R24	Z	220	½W	5%	193522200
R25	X	2.2M	½W	10%	172362200
R26	Z	220	½W	5%	193522200
R27	Z	180	½W	5%	193521800
R28	Z	1000	½W	5%	193531000
R29	V	1206	To Spec		B16110028
R30	V	1179	To Spec		B16110028
R31	V	1.5	½W	1%	198301503
R32	V	131	To Spec		B16110028
R33	V	1206	To Spec		B16110028
R34	Z	24K	½W	1%	195442400
R37	V	10.2K	½W	.5%	198241021
R38	Z	33K	½W	5%	193543300
R39	Z	2200	½W	5%	193532200
R40	Z	470K	½W	5%	193554700
R41	Z	470K	½W	5%	193554700
R42	Z	10	½W	5%	193511000
R43	X	100K	½W	10%	172351000
R44	X	82K	½W	10%	172348200
R45	X	82K	½W	10%	172348200
RV1		1000	¾W	20%	124031000
RV2		100	¾W	20%	124021000
C1	B	0.1	250V	10%	225751000
C3	A	330p	125V	10%	210223300
C4	B	0.22	100V	10%	225452200
C5	A	3300p	125V	2.5%	210133300
C7	J	100	30V	-20% +100%	270781000
C8	A	330p	125V	10%	210223300
C9	B	2.2	100V	10%	225462200
C10	G	0.1	30V	+50% -25%	242051000
C11	B	1.0	100V	10%	225461000
C12	C	.015	400V	10%	227441500
C14	A	180p	125V	2.5%	210121800
C15	B	0.22	100V	10%	225452200
C16	J	500	25V	-20% +100%	260785000
C17	C	1000p	125V	10%	210231000
C18	J	100	30V	-20% +100%	270781000
C19	J	320	4V	-10% +100%	208600192
C20	G	0.1	30V	-25% +50%	242051000

MR1	IN3595	Motorola	300523590
MR2	IN3595	Motorola	300523590
MR3	SZD8.2	Solartron	300521330
MR4	SZD8.2	Solartron	300521330
MR5	SZD5.6	Solartron	300521450
MR6	SD3	Solartron	300522160
MR7	SZD3.3	Solartron	300521860
MR8	SD3	Solartron	300522160
MR9	SD3	Solartron	300522160
MR10	SZD8.2	Solartron	300521330
MR11	SD3	Solartron	300522160
MR12	SD3	Solartron	300523730
MR13	BYX10		300523730
MR14	BYX10		300523730
MR15	SD3	Solartron	300522160
VT1	2N2484	Texas	300552860
VT2	2N2484		300552860
VT3	BC107/S	Mullard	300553320
VT4	2N2484		300552860
VT5	2N2484	Texas	300552860
VT6	SM6526	Motorola	300552990
VT7	BC107/S	Mullard	300553320
VT8	SM6526	Motorola	300552990
VT9	BC107/S	Mullard	300553320
VT10	TIXS78		300553820
PLA	Conn. 16 Way Fixed Plug		352316060

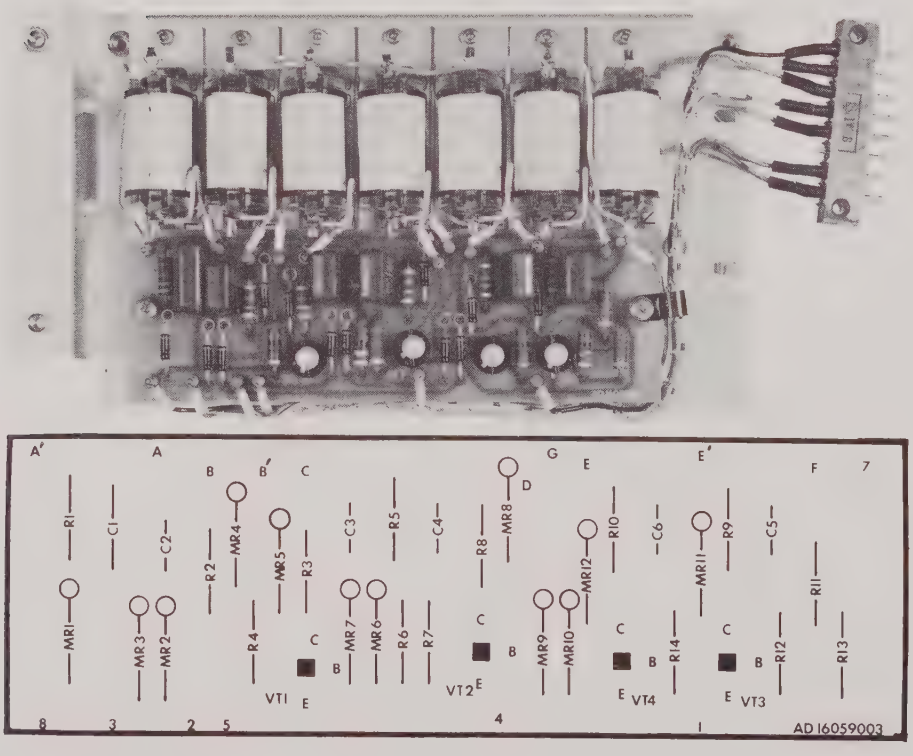




Component Location - Board 2

Component Parts List for Printed Circuit Board 16059003

Cct. Ref.		General Description			Solartron Part No.
R1	X	22K	½W	10%	172342200
R2	X	47K	½W	10%	172344700
R3	X	47K	½W	10%	172344700
R4	X	100	½W	10%	172321000
R5	X	2200	½W	10%	172332200
R6	X	10K	½W	10%	172341000
R7	X	2200	½W	10%	172332200
R8	X				
to	X	47K	½W	10%	172344700
R10					
R11	X	2200	½W	10%	172332200
R12	X	10K	½W	10%	172341000
R13	X	2200	½W	10%	172332200
R14	X	100	½W	10%	172321000
C1	B	0.47	100V	10%	225454700
C2 to C6	B	0.22	100V	10%	225452200
MR1 to MR12		SD3	Solartron		300522160
VT1 to VT4		BC107/S			300553320



Component Location - Board 3

Component Parts List for 1610 General Assembly

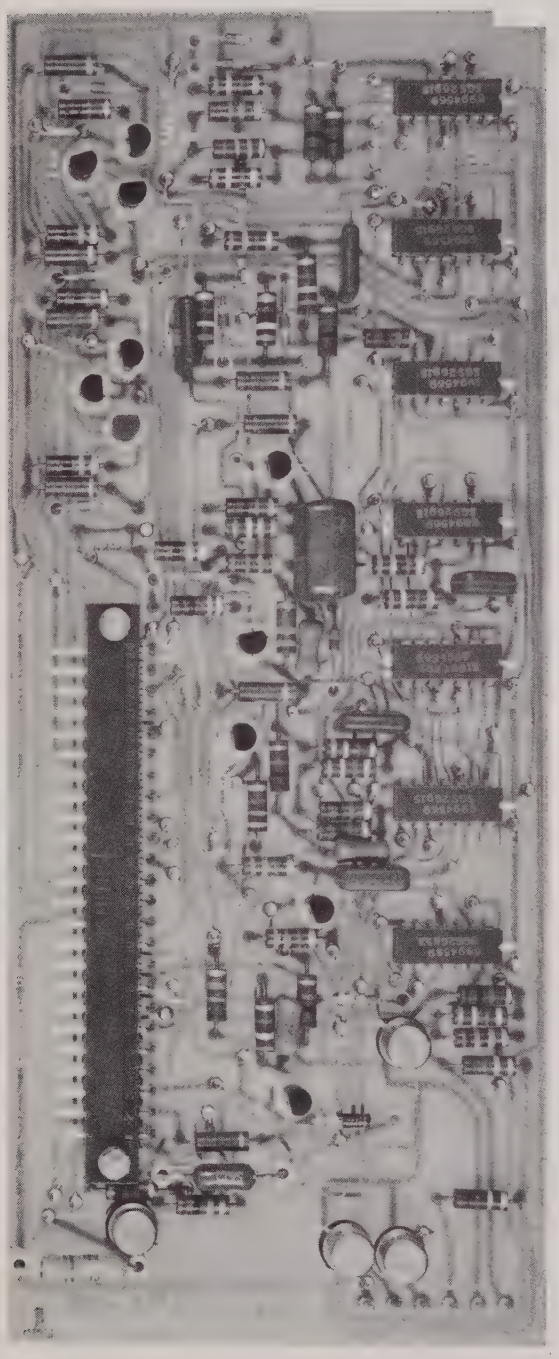
Cct. Ref.		General Description			Solartron Part No.
R4	X	1M	½W	10%	172361000
R5	X	1M	½W	10%	172361000
C1	D	0.047	630V	20%	208300059
C2	D	0.047	630V	20%	208300059
PLA		Conn. Plug Fxd			352303030
T1		Mains Transformer			B16100002
T2		Transformer (Screened)			B16100001
TL.1		Conn. Terminal Red			355000770
TL.2		Conn. Terminal Black			355000750
TL.3		Conn. Terminal Green			355000760
ILP1 to ILP4		Lamp 16L			300720140
ILP5		Neon Lamp Assy.			300720340
ILP6 to ILP8		Neon NE2H			300720220
ILP9		HYvac XNS1 Digital Indicators			300011390
ILP10		NE2H			300720220
ILP11		NE2H			300720220
S.A.		Mains Toggle Switch ON/OFF			376000300
S.B.		Switch Pushbutton			B16100013
SKT B		Conn. Socket 36 Way			352536030
SKT C		Conn. Socket 36 Way			352536030
SKT D		Conn. Socket 18 Way			352518090
SKT E		Conn. Socket Fixed			352503050
FS.1		Fuse Link 500mA Slo-Blo			360105060
MSP.1		Mains Selector Panel			399000060

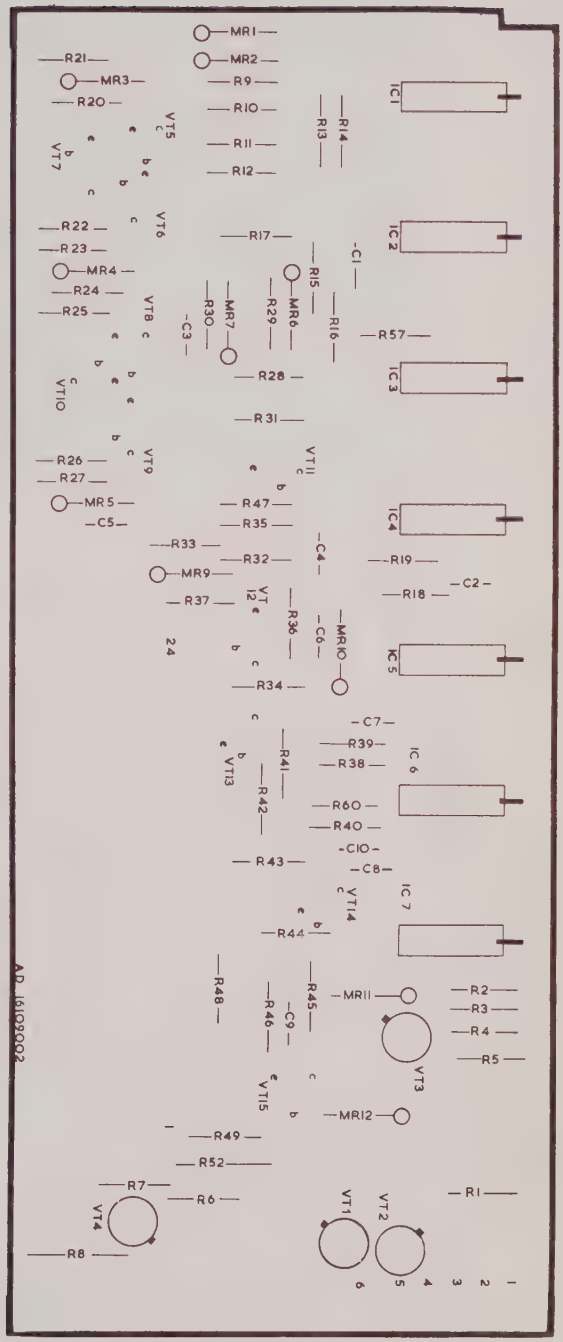
Component Parts List
for
Printed Circuit Board 16109002

Cct. Ref.		General Description			Solartron Part No.
R1	X	150K	½W	10%	172351500
R2	X	1000	½W	10%	172331000
R3	X	3900	½W	10%	172333900
R4	X	27K	½W	10%	172342700
R5	X	150K	½W	10%	172351500
R6	X	10K	½W	10%	172341000
R7	X	47K	½W	10%	172344700
R8	Z	68K	1W	5%	193446800
R9	X	3900	½W	10%	172333900
R10	X	27K	½W	10%	172342700
R11	X	27K	½W	10%	172342700
R12	X	3900	½W	10%	172333900
R13	X	1000	½W	10%	172331000
R14	X	1000	½W	10%	172331000
R15	X	3900	½W	10%	172333900
R16	X	1000	½W	10%	172331000
R17 to R19	X	3900	½W	10%	172333900
R20	X	1000	½W	10%	172331000
R21	X	2200	½W	10%	172332200
R22	X	10K	½W	10%	172341000
R23	X	2200	½W	10%	172332200
R24	X	1000	½W	10%	172331000
R25	X	2200	½W	10%	172332200
R26	X	10K	½W	10%	172341000
R27	X	2200	½W	10%	172332200
R28	X	2.2M	½W	10%	172362200
R29	X	3900	½W	10%	172333900
R30	X	6800	½W	10%	172336800
R31	X	2200	½W	10%	172332200
R32	X	22K	½W	10%	172342200
R33	X	10K	½W	10%	172341000
R34	X	2200	½W	10%	172332200
R35	X	39K	½W	10%	172343900
R36	X	3300	½W	10%	172333300
R37	X	10K	½W	10%	172341000
R38	X	3900	½W	10%	172333900
R39	X	3900	½W	10%	172333900
R40	X	1000	½W	10%	172331000
R41	X	1000	½W	10%	172331000
R42	X	4700	½W	10%	172334700
R43	X	3300	½W	10%	172333300
R44	X	4700	½W	10%	172334700
R45	X	1000	½W	10%	172331000
R46	X	3900	½W	10%	172333900
R47	X	1000	½W	10%	172331000
R48	X	27K	½W	10%	172342700
R49	X	2200	½W	10%	172342700
R52	Y	56	2.6W	5%	173415600
R57	X	1000	½W	10%	172331000
R60	X	1000	½W	10%	172331000

C1	B	0.022	250V	10%	225742200
C2	B	0.047	100V	10%	225444700
C3	B	0.022	250V	10%	225742200
C4	B	0.68	100V	10%	225456800
C5	F	47p	750V	10%	240414700
C6	F	68p	750V	10%	240416800
C7	B	0.01	400V	10%	226041000
C8	B	0.033	250V	10%	225743300
C9	F	100p	500V	10%	208400044
C10	F	68p	750V	10%	240416800

IC1 to IC6	Integrated Cct. 846N		510000160
IC7	Integrated Cct. 845N		510000150
MR1 to MR7	SD3	Solartron	300522160
MR9 to MR11	SD3	Solartron	300522160
MR12	IN4733A		300524370
VT1 to VT4	A1778/2		300551430
VT5 to VT15	D2039/D1501		300553421
	Connector PCB 24 way		352324090

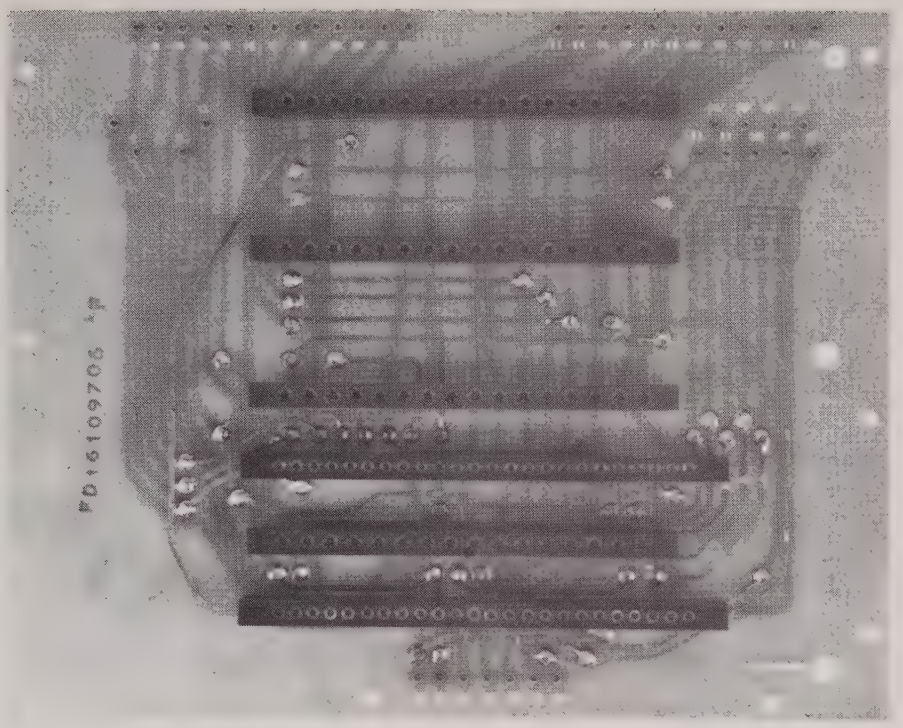


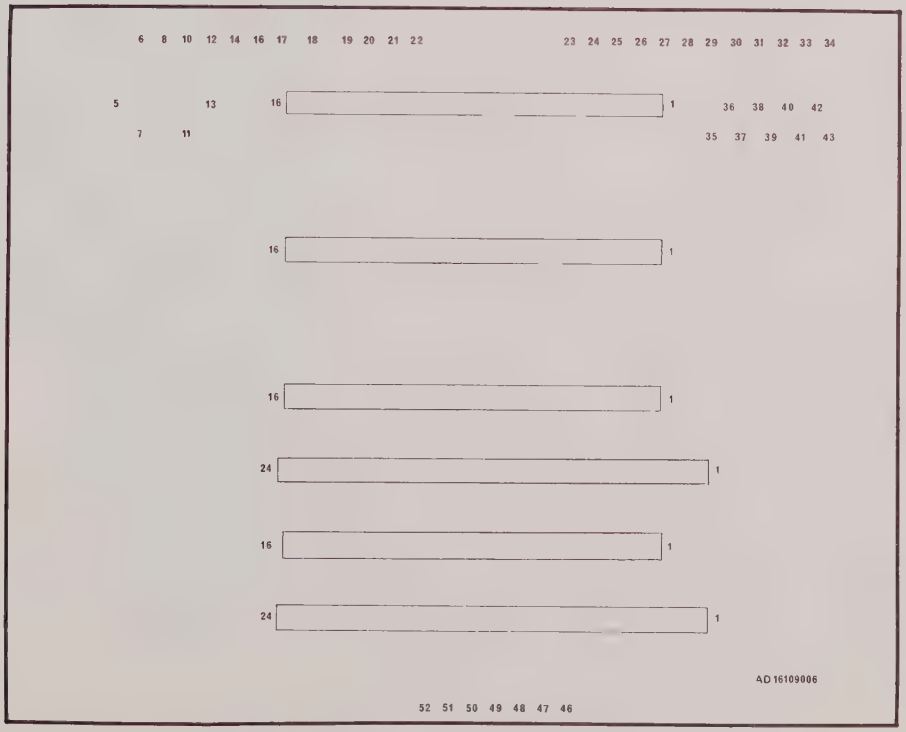


Component Location - Board 2

Component Parts List
for
Printed Circuit Board 16109006

Cct. Ref.	General Description	Solartron Part No.
SKT.A	Conn. Socket 24 Way	352524120
SKT.B	Conn. Socket 24 Way	352524120
SKT.C	Conn. Socket 24 Way	352524120
SKT.D to SKT.H	Conn. Socket 16 Way	352516100

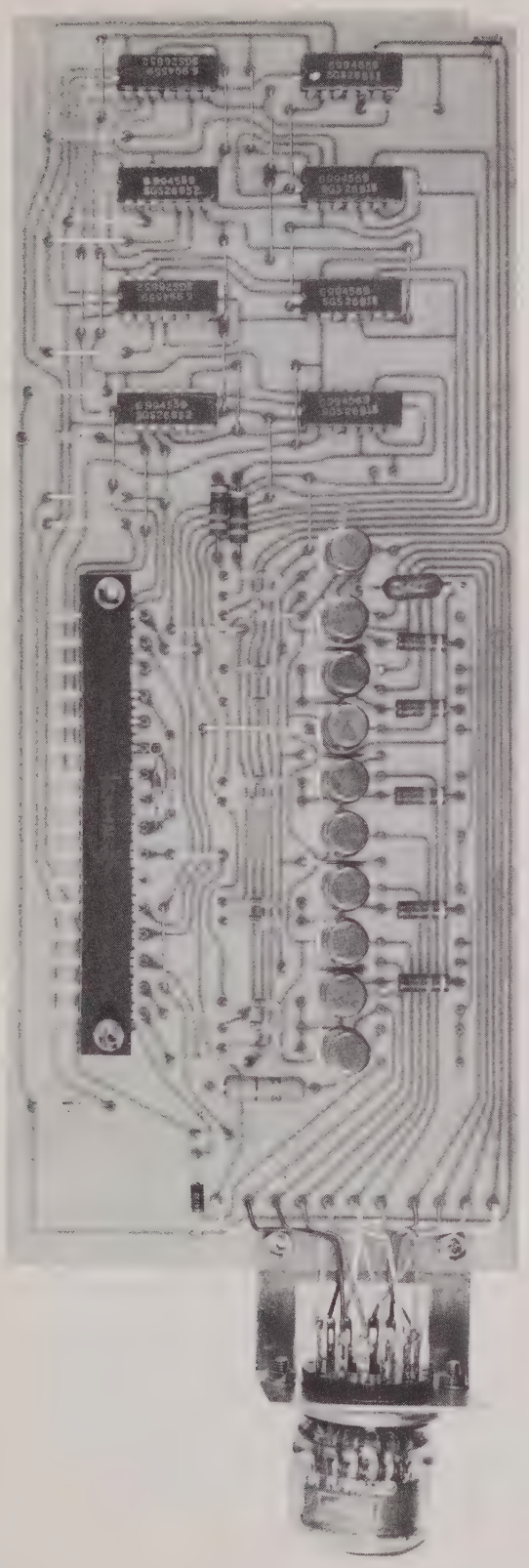


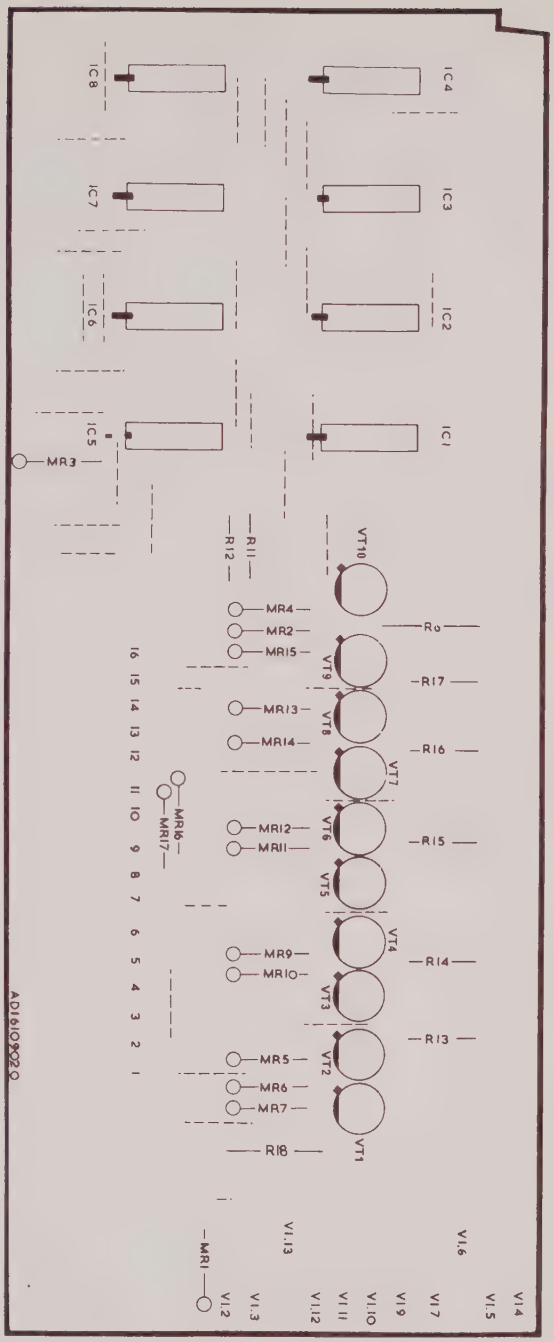


Component Location - Board 6

Component Parts List
for
Printed Circuit Board 16109020

Cct. Ref.		General Description			Solartron Part No.
R6	Y	56	2.6W	5%	173415600
R11	X	330	½W	10%	172323300
R12	X	330	½W	10%	172323300
R13 To R17	X	15K	½W	10%	172341500
R18	Z	47K	1W	5%	193444700
MR1		1N4733A			300524370
MR2 to MR7		SD3	Solartron		300522160
MR9 to MR17		SD3	Solartron		300522160
VT1 to VT10		A1778/2			300551430
IC1 to IC4		SN845N			510000150
IC5 to IC8		SN845N			510000150
PLA		Connector Plug 16 Way			352316050

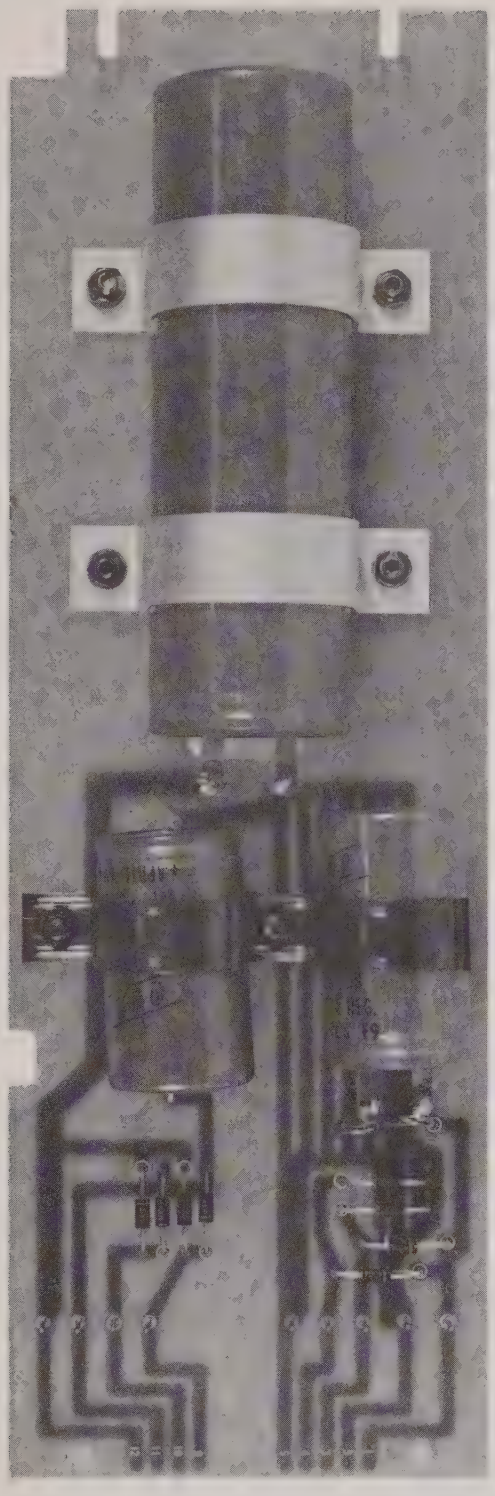


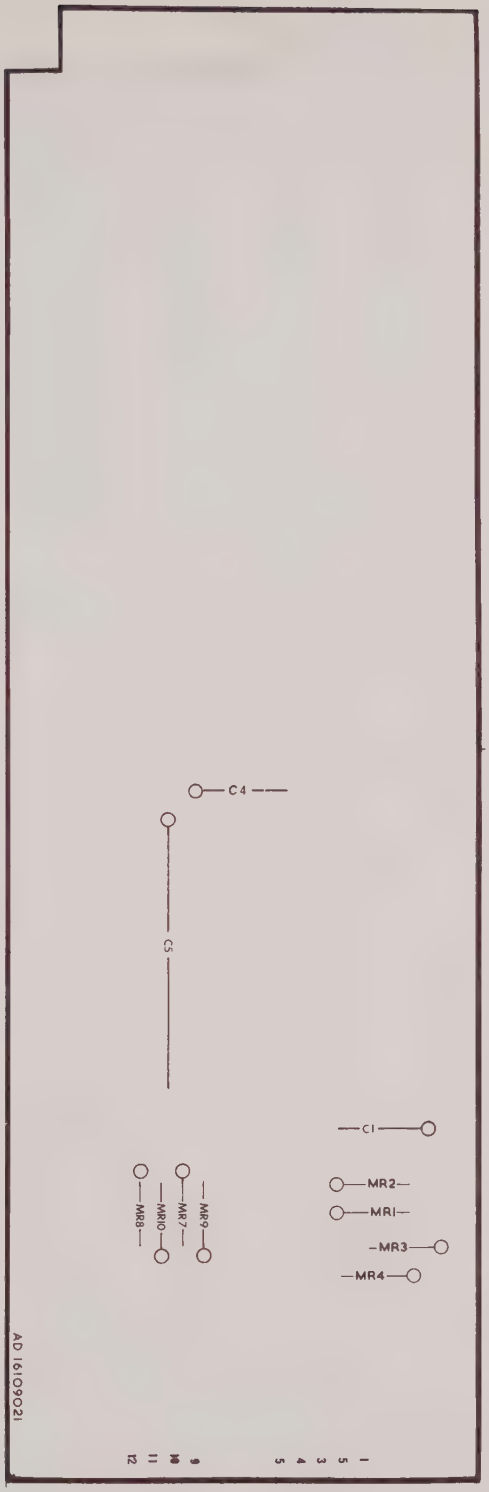


Component Location - Board 20

Component Parts List
for
Printed Circuit Board 16109021

Cct. Ref.	General Description				Solartron Part No.
C1	J	32	350V	-20% +50%	272373200
C4	J	10,000	15V	-20% +100%	208600159
C5	J	1,000	25V	-20V +100%	270791000
MR1 to MR4	IN4004				300522070
MR7 to MR10	IN4001				300522060

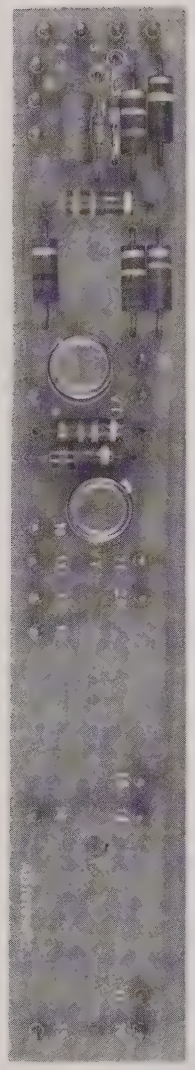


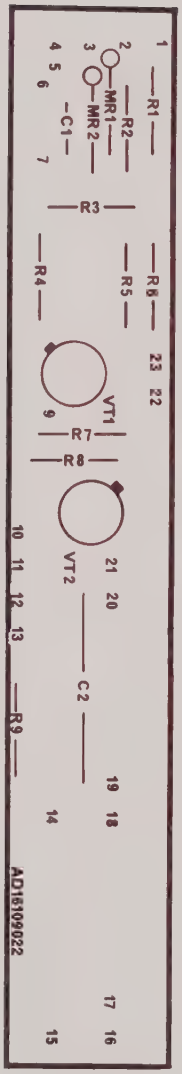


Component Location - Board 21

Component Parts List
for
Printed Circuit Board 16109022

Cct. Ref.		General Description			Solartron Part No.
R1	X	150K	½W	10%	172351500
R2	X	270K	½W	10%	172352700
R3	X	4700	½W	10%	172334700
R4	X	1000	½W	10%	172331000
R5	X	220K	½W	10%	172352200
R6	X	220K	½W	10%	172352200
R7	X	33K	½W	10%	172343300
R8	X	1000	½W	10%	172331000
R9	X	68K	.25W	10%	172346800
C1	F	4700p	350V	25%	208400059
C2		0.22μF	400V	±2%	220652200
MR1		SD3	Solartron		300522160
MR2		SD3	Solartron		300522160
VT1		A1778/2			300551430
VT2		A1778/2			300551430





Component Location - Board 22

FAN OUT UNIT
EX3054

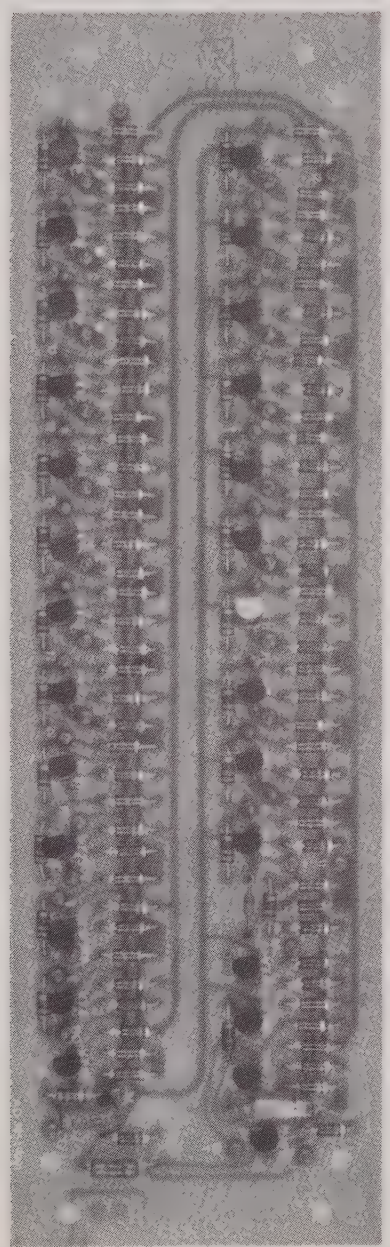
Component Parts List for 3054 Main Assembly

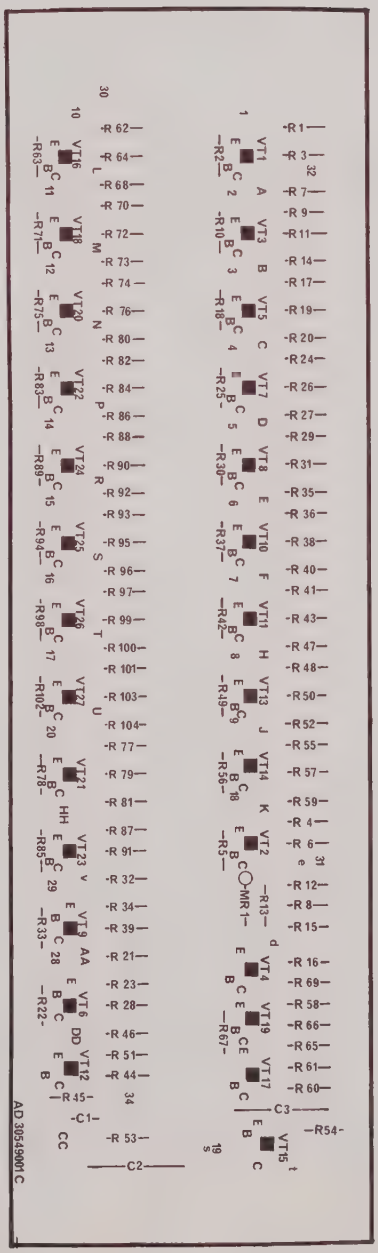
Cct. Ref.	General Description	Solartron Part No.
PLA	Conn. Plug Fixed 36 Way	352336010
SKTA	Conn. Skt. Fixed 50 Way	354002330

Component Parts List for Printed Circuit Board 30549001

R1	X	6800	¼W	10%	172036800
R2	X	3300	¼W	10%	172033300
R3	X	56K	¼W	10%	172045600
R4	X	6800	¼W	10%	172036800
R5	X	3300	¼W	10%	172033300
R6	X	56K	¼W	10%	172045600
R7	X	1500	¼W	10%	172031500
R8	X	1500	¼W	10%	172031500
R9	X	6800	¼W	10%	172036800
R10	X	3300	¼W	10%	172033300
R11	X	56K	¼W	10%	172045600
R12	X	6800	¼W	10%	172036800
R13	X	3300	¼W	10%	172033300
R14	X	1500	¼W	10%	172031500
R15	X	56K	¼W	10%	172045600
R16	X	1500	¼W	10%	172031500
R17	X	6800	¼W	10%	172036800
R18	X	3300	¼W	10%	172033300
R19	X	56K	¼W	10%	172045600
R20	X	1500	¼W	10%	172031500
R21	X	6800	¼W	10%	172036800
R22	X	3300	¼W	10%	172033300
R23	X	56K	¼W	10%	172045600
R24	X	6800	¼W	10%	172036800
R25	X	3300	¼W	10%	172033300
R26	X	56K	¼W	10%	172045600
R27	X	1500	¼W	10%	172031500
R28	X	1500	¼W	10%	172031500
R29	X	6800	¼W	10%	172036800
R30	X	3300	¼W	10%	172033300
R31	X	56K	¼W	10%	172045600
R32	X	6800	¼W	10%	172036800
R33	X	3300	¼W	10%	172033300
R34	X	56K	¼W	10%	172045600
R35	X	1500	¼W	10%	172031500
R36	X	6800	¼W	10%	172036800
R37	X	3300	¼W	10%	172033300
R38	X	56K	¼W	10%	172045600
R39	X	1500	¼W	10%	172031500
R40	X	1500	¼W	10%	172031500
R41	X	6800	¼W	10%	172036800
R42	X	3300	¼W	10%	172033300
R43	X	56K	¼W	10%	172045600
R44	X	6800	¼W	10%	172036800
R45	X	3300	¼W	10%	172033300
R46	X	56K	¼W	10%	172045600
R47	X	1500	¼W	10%	172031500
R48	X	6800	¼W	10%	172036800
R49	X	3300	¼W	10%	172033300
R50	X	56K	¼W	10%	172045600
R51	X	1500	¼W	10%	172031500
R52	X	1500	¼W	10%	172031500
R53	X	56K	¼W	10%	172045600
R54	X	12K	¼W	10%	172041200
R55	X	6800	¼W	10%	172036800
R56	X	3300	¼W	10%	172033300
R57	X	56K	¼W	10%	172045600
R58	X	1000	¼W	10%	172031000
R59	X	1500	¼W	10%	172031500
R60	X	10K	¼W	10%	172041000
R61	X	56K	¼W	10%	172045600
R62	X	6800	¼W	10%	172036800
R63	X	3300	¼W	10%	172033300
R64	X	56K	¼W	10%	172045600
R65	X	1000	¼W	10%	172031000
R66	X	2200	¼W	10%	172032200
R67	X	6800	¼W	10%	172036800
R68	X	1500	¼W	10%	172031500
R69	X	12K	¼W	10%	172041200
R70	X	6800	¼W	10%	172036800
R71	X	3300	¼W	10%	172033300
R72	X	56K	¼W	10%	172045600
R73	X	1500	¼W	10%	172031500
R74	X	6800	¼W	10%	172036800
R75	X	3300	¼W	10%	172033300
R76	X	56K	¼W	10%	172045600
R77	X	6800	¼W	10%	172036800
R78	X	3300	¼W	10%	172033300
R79	X	56K	¼W	10%	172045600
R80	X	1500	¼W	10%	172031500
R81	X	6800	¼W	10%	172036800
R82	X	6800	¼W	10%	172036800
R83	X	3300	¼W	10%	172033300
R84	X	56K	¼W	10%	172045600
R85	X	3300	¼W	10%	172033300
R86	X	1500	¼W	10%	172031500
R87	X	56K	¼W	10%	172045600
R88	X	6800	¼W	10%	172036800
R89	X	3300	¼W	10%	172033300
R90	X	56K	¼W	10%	172045600
R91	X	1500	¼W	10%	172031500
R92	X	1500	¼W	10%	172031500
R93	X	6800	¼W	10%	172036800
R94	X	3300	¼W	10%	172033300
R95	X	56K	¼W	10%	172045600
R96	X	1500	¼W	10%	172031500
R97	X	6800	¼W	10%	172036800
R98	X	3300	¼W	10%	172033300
R99	X	56K	¼W	10%	172045600
R100	X	1500	¼W	10%	172031500
R101	X	6800	¼W	10%	172036800
R102	X	3300	¼W	10%	172033300
R103	X	56K	¼W	10%	172045600

R104	X	1500	¼W	10%	172031500
C1	F	100p	500V	10%	208400044
C2	C	470p	400V	10%	221324700
C3	B	0.01	400V	10%	220841000
MR1		SD3	Solartron		300522160
VT1 to VT21		D2039/D1501			300553421



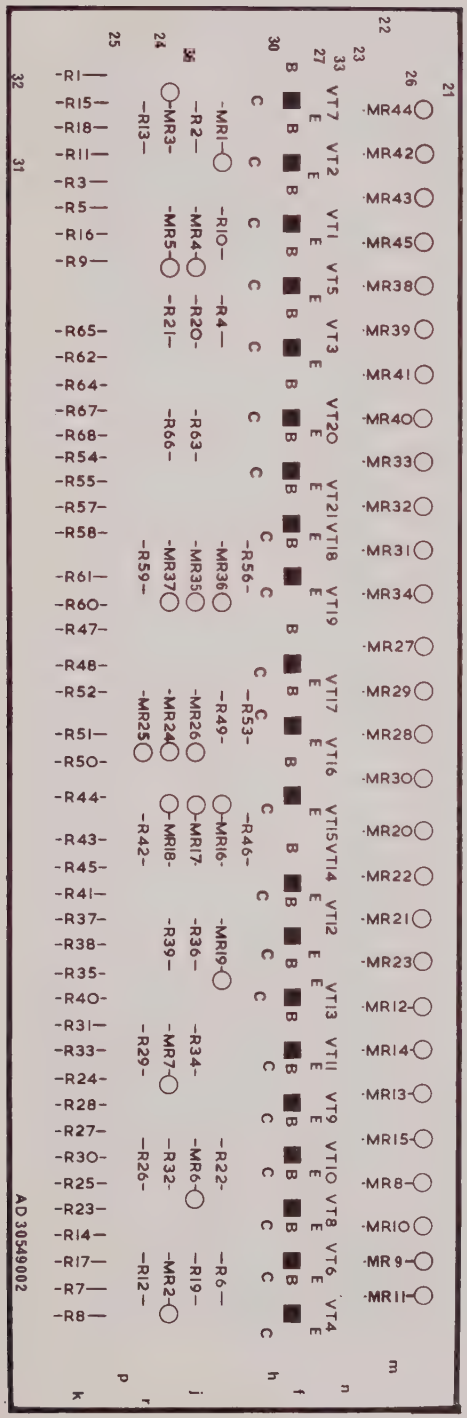


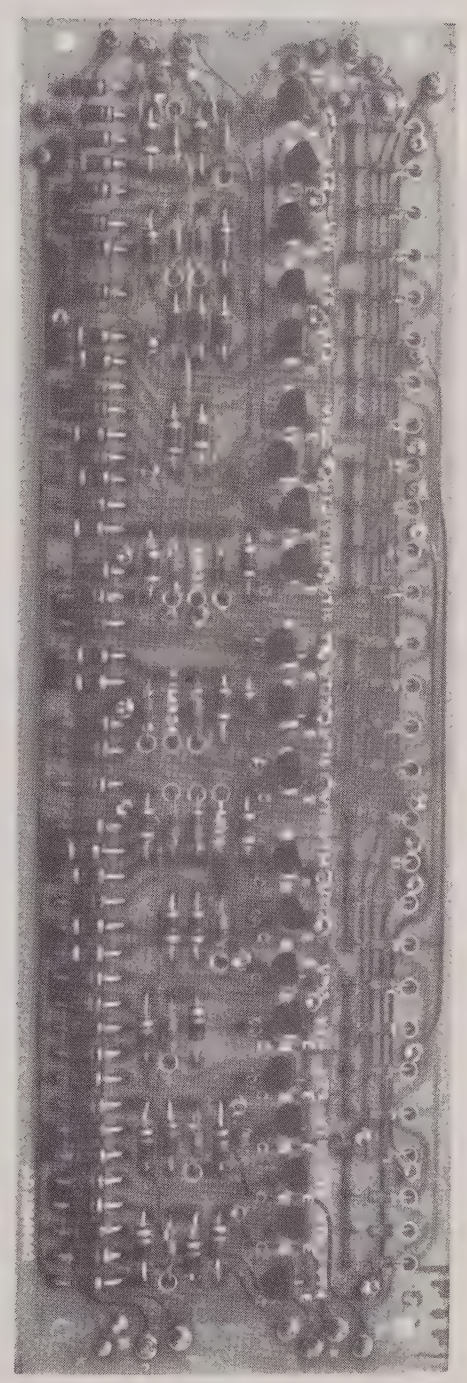
Component Location - Board 1

Component Parts List
for
Printed Circuit Board 30549002

Cct. Ref.		General Description			Solartron Part No.
R1	X	6800	¼W	10%	172036800
R2	X	6800	¼W	10%	172036800
R3	X	56K	¼W	10%	172045600
R4	X	56K	¼W	10%	172045600
R5	X	4700	¼W	10%	172034700
R6	X	18K	¼W	10%	172041800
R7	X	56K	¼W	10%	172045600
R8	X	8200	¼W	10%	172038200
R9	X	12K	¼W	10%	172041200
R10	X	3300	¼W	10%	172033300
R11	X	4700	¼W	10%	172034700
R12	X	10K	¼W	10%	172041000
R13	X	4700	¼W	10%	172034700
R14	X	56K	¼W	10%	172045600
R15	X	56K	¼W	10%	172045600
R16	X	10K	¼W	10%	172041000
R17	X	8200	¼W	10%	172038200
R18	X	1500	¼W	10%	172031500
R19	X	10K	¼W	10%	172041000
R20	X	8200	¼W	10%	172038200
R21	X	18K	¼W	10%	172041800
R22	X	18K	¼W	10%	172041800
R23	X	56K	¼W	10%	172045600
R24	X	56K	¼W	10%	172045600
R25	X	8200	¼W	10%	172038200
R26	X	10K	¼W	10%	172041000
R27	X	56K	¼W	10%	172045600
R28	X	8200	¼W	10%	172038200
R29	X	10K	¼W	10%	172041000
R30	X	8200	¼W	10%	172038200
R31	X	56K	¼W	10%	172045600
R32	X	56K	¼W	10%	172045600
R33	X	8200	¼W	10%	172038200
R34	X	10K	¼W	10%	172041000
R35	X	4700	¼W	10%	172034700
R36	X	4700	¼W	10%	172034700
R37	X	56K	¼W	10%	172045600
R38	X	4700	¼W	10%	172034700
R39	X	4700	¼W	10%	172034700
R40	X	56K	¼W	10%	172045600
R41	X	4700	¼W	10%	172034700
R42	X	4700	¼W	10%	172034700
R43	X	1500	¼W	10%	172031500
R44	X	56K	¼W	10%	172045600
R45	X	4700	¼W	10%	172034700
R46	X	4700	¼W	10%	172034700
R47	X	56K	¼W	10%	172045600
R48	X	4700	¼W	10%	172034700
R49	X	4700	¼W	10%	172034700
R50	X	56K	¼W	10%	172045600
R51	X	1500	¼W	10%	172031500
R52	X	4700	¼W	10%	172034700
R53	X	4700	¼W	10%	172034700
R54	X	56K	¼W	10%	172045600
R55	X	4700	¼W	10%	172034700
R56	X	4700	¼W	10%	172034700
R57	X	56K	¼W	10%	172045600
R58	X	4700	¼W	10%	172034700
R59	X	4700	¼W	10%	172034700
R60	X	56K	¼W	10%	172045600
R61	X	1500	¼W	10%	172031500
R62	X	4700	¼W	10%	172034700
R63	X	4700	¼W	10%	172034700
R64	X	56K	¼W	10%	172045600
R65	X	4700	¼W	10%	172034700
R66	X	4700	¼W	10%	172034700
R67	X	56K	¼W	10%	172045600
R68	X	4700	¼W	10%	172034700

MR1 to MR15	SD3	Solartron	300522160
MR17 to MR23	SD3	Solartron	300522160
MR25 to MR34	SD3	Solartron	300522160
MR36 to MR45	SD3	Solartron	300522160

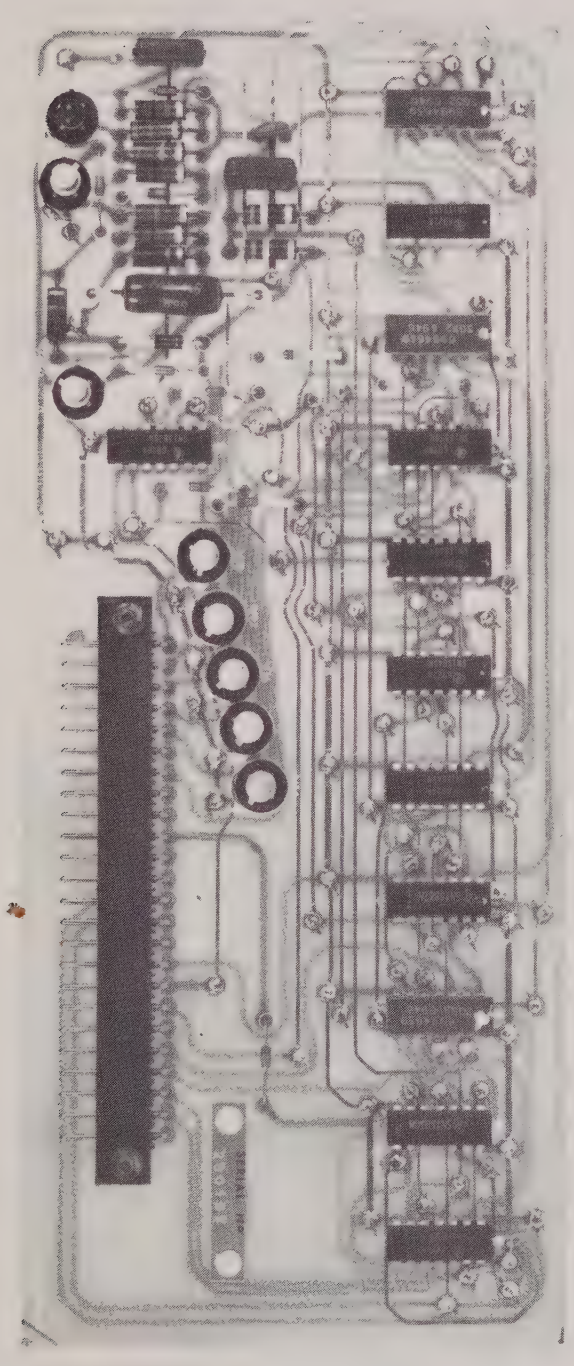


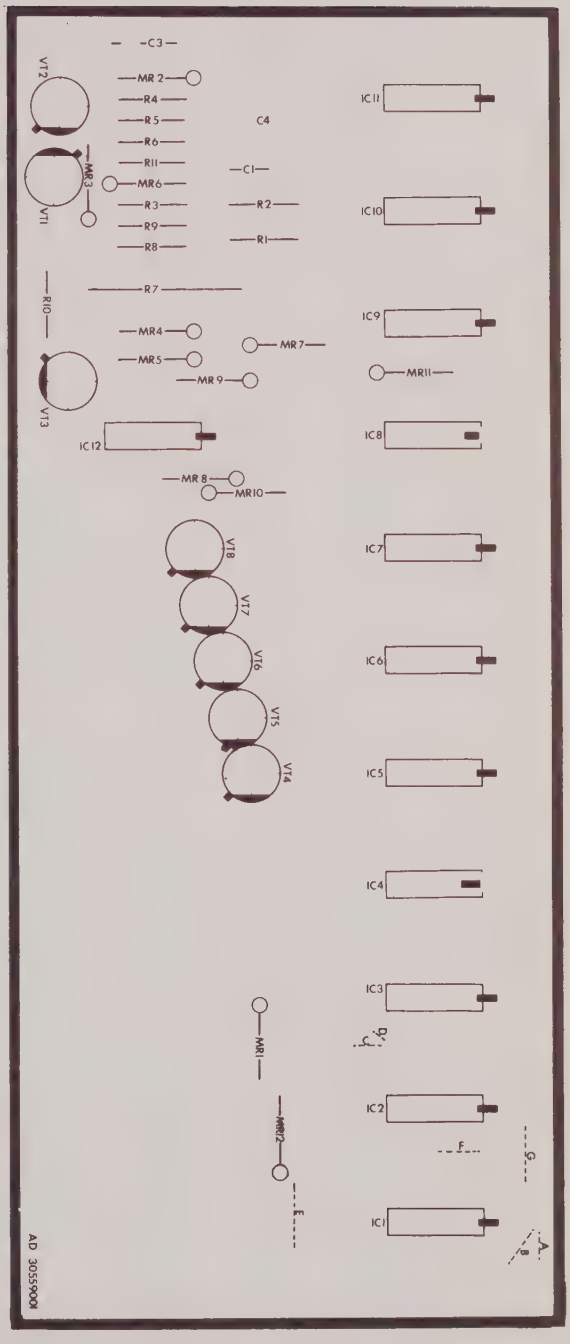


Component Location - Board 2

Component Parts List for Printed Circuit Board 30559001

Cct. Ref.		General Description			Solartron Part No.
R1	X	3900	½W	10%	172333900
R2	X	3900	½W	10%	172333900
R3	X	5600	½W	10%	172335600
R4	X	10M	½W	10%	172371000
R5	X	15K	½W	10%	172341500
R6	X	22K	½W	10%	172342200
R7	Y	56	6W	5%	173715600
R8	X	10K	½W	10%	172341000
R9	X	1000	½W	10%	172331000
R10	X	15K	½W	10%	172341500
R11	X	1000	½W	10%	172331000
C1	B	0.022	400V	10%	226042200
C3	B	0.015	400V	10%	226041500
C4		470p	500V	10%	208450045
IC1		Integrated Circuit SN15836N			510000290
IC2		Integrated Circuit SN15830N			510000100
IC3		Integrated Circuit SN15846N			510000160
IC4		Integrated Circuit SN15862N			510000200
IC5 to IC7		Integrated Circuit SN15845N			510000150
IC8		Integrated Circuit SN15836N			510000290
IC9		Integrated Circuit SN15846N			510000160
IC10		Integrated Circuit SN15845N			510000150
IC11		Integrated Circuit SN15846N			510000160
IC12		Integrated Circuit SN15836N			510000290
PLA		Conn. Plug Fixed 24 Way			352324090
MR1 to MR3		SD3	Solartron		300522160
MR4		IN4733	Motorola		300524370
MR5 to MR11		SD3	Solartron		300522160
VT1		BC107/S	Mullard		300553320
VT2		2N4303	Texas		300553160
VT3 to VT8		BC107/S	Mullard		300553320





Component Location - EX3055

FAN OUT UNIT
EX3052

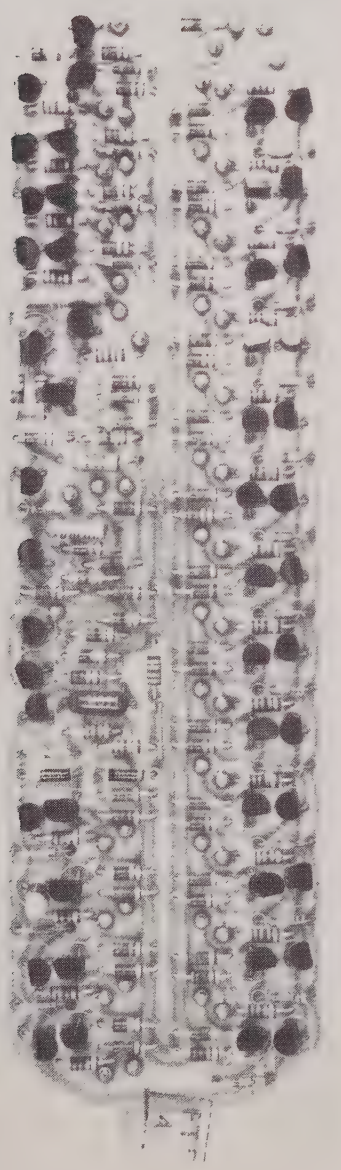
Component Parts List for 3052 Main Assembly

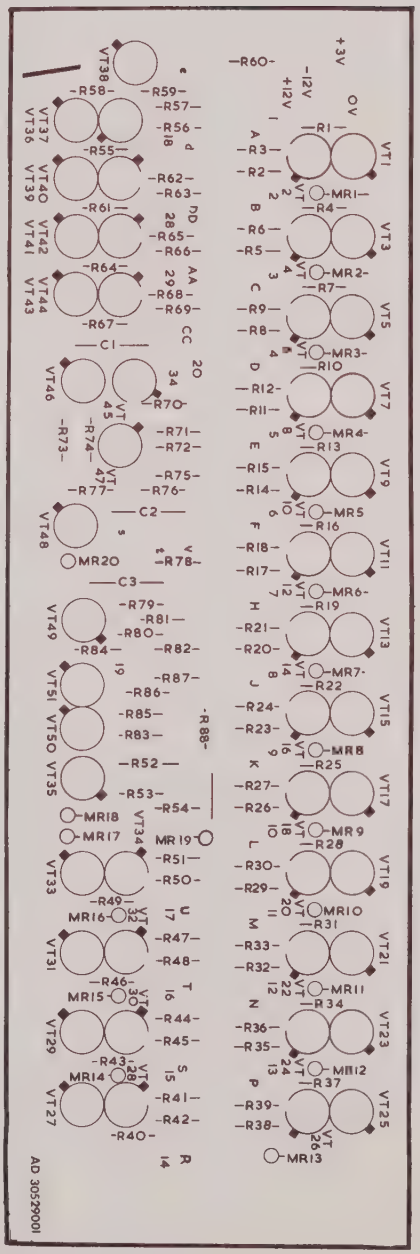
Cct. Ref.	General Description	Solartron Part No.
PLA	Plug fixed 36 way	352336010
SK TA	Socket fixed 50 way	354002330

Component Parts List for Printed Circuit Board 30529001

Cct. Ref.		General Description			Solartron Part No.
R1	X	33k	½W	10%	172043300
R2	X	22k	½W	10%	172042200
R3	X	1500	½W	10%	172031500
R4	X	33k	½W	10%	172043300
R5	X	22k	½W	10%	172042200
R6	X	1500	½W	10%	172031500
R7	X	33k	½W	10%	172043300
R8	X	22k	½W	10%	172042200
R9	X	1500	½W	10%	172031500
R10	X	33k	½W	10%	172043300
R11	X	22k	½W	10%	172042200
R12	X	1500	½W	10%	172031500
R13	X	33k	½W	10%	172043300
R14	X	22k	½W	10%	172042200
R15	X	1500	½W	10%	172031500
R16	X	33k	½W	10%	172043300
R17	X	22k	½W	10%	172042200
R18	X	1500	½W	10%	172031500
R19	X	33k	½W	10%	172043300
R20	X	22k	½W	10%	172042200
R21	X	1500	½W	10%	172031500
R22	X	33k	½W	10%	172043300
R23	X	22k	½W	10%	172042200
R24	X	1300	½W	10%	172031500
R25	X	33k	½W	10%	172043300
R26	X	22k	½W	10%	172042200
R27	X	1500	½W	10%	172031500
R28	X	33k	½W	10%	172043300
R29	X	22k	½W	10%	172042200
R30	X	1500	½W	10%	172031500
R31	X	33k	½W	10%	172043300
R32	X	22k	½W	10%	172042200
R33	X	1500	½W	10%	172031500
R34	X	33k	½W	10%	172043300
R35	X	22k	½W	10%	172042200
R36	X	1500	½W	10%	172031500
R37	X	33k	½W	10%	172043300
R38	X	22k	½W	10%	172042200
R39	X	1500	½W	10%	172031500
R40	X	33k	½W	10%	172043300
R41	X	22k	½W	10%	172042200
R42	X	1500	½W	10%	172031500
R43	X	33k	½W	10%	172043300
R44	X	22k	½W	10%	172042200
R45	X	1500	½W	10%	172031500
R46	X	33k	½W	10%	172043300
R47	X	22k	½W	10%	172042200
R48	X	1500	½W	10%	172031500
R49	X	33k	½W	10%	172043300
R50	X	22k	½W	10%	172042200
R51	X	1500	½W	10%	172031500
R52	Y	150	2.5W	5%	172021500
R53	X	33k	½W	10%	172043300
R54	X	33k	½W	10%	172043300
R55	X	33k	½W	10%	172043300
R56	X	22k	½W	10%	172042200
R57	X	1500	½W	10%	172031500
R58	X	100k	½W	10%	172051000
R59	X	22k	½W	10%	172042200
R60	X	1500	½W	10%	172031500
R61	X	33k	½W	10%	172043300
R62	X	22k	½W	10%	172042200
R63	X	1500	½W	10%	172031500
R64	X	33k	½W	10%	172043300
R65	X	22k	½W	10%	172042200
R66	X	1500	½W	10%	172031500
R67	X	33k	½W	10%	172043300
R68	X	22k	½W	10%	172042200
R69	X	1500	½W	10%	172031500
R70	X	33k	½W	10%	172043300
R71	X	22k	½W	10%	172043300
R73	X	100k	½W	10%	172051000
R74	X	22k	½W	10%	172042200
R75	X	1500	½W	10%	172031500
R76	X	100k	½W	10%	172051000
R77	X	15k	½W	10%	172041500
R78	X	2200	½W	10%	172032200
R79	X	15k	½W	10%	172041500
R80	X	100k	½W	10%	172051000
R81	X	1000	½W	10%	172031000
R82	X	2200	½W	10%	172032200
R83	X	22k	½W	10%	172042200
R84	X	15k	½W	10%	172041500
R85	X	10k	½W	10%	172041000
R86	X	10k	½W	10%	172041000
R87	X	100k	½W	10%	172051000
R88	X	33k	½W	10%	172043300
C1	C	100p	160V	10%	221321000
C2	C	680p	160V	10%	221326800
C3	C	1000p	160V	10%	221331000
VT1 to VT49		D1561			300552991
VT50		D2039			300553421

Cct. Ref.	General Description	Solartron Part No.
VT51	D2039	300553421
MR1 to MR16	SD3	300522160
MR17	Diode Zener 3.0V	300523880
MR18	SD3	300522160
MR19	Diode Zener 5.6V	300521450
MR20	SD3	300522160



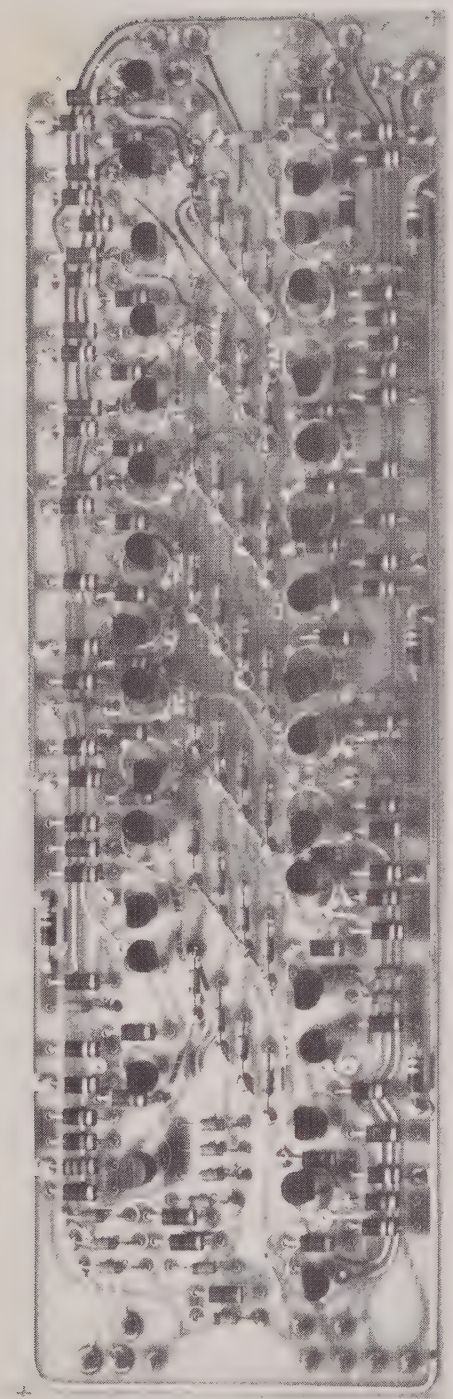


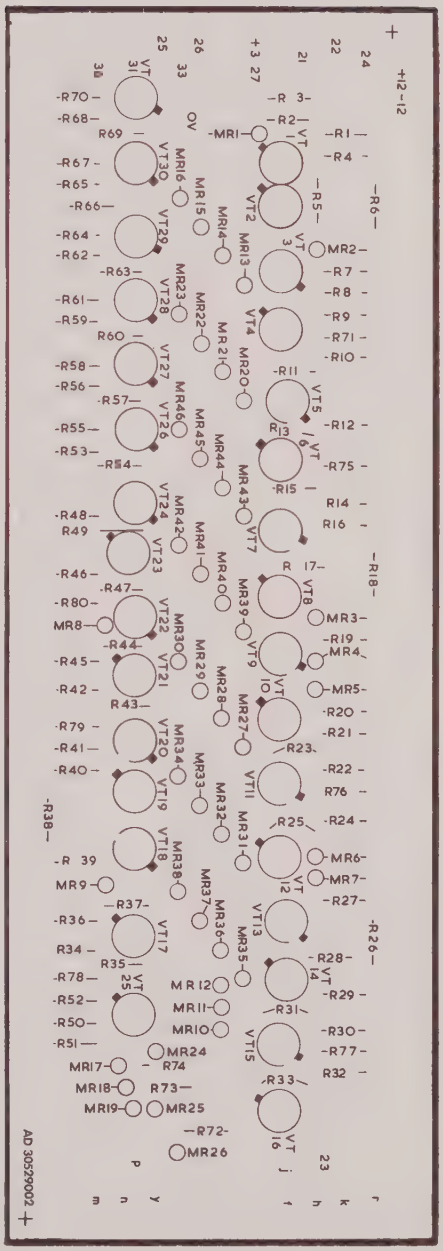
Component Location - Board 1

Component Parts List for Printed Circuit Board 30529002

Cct. Ref.	General Description				Solartron Part No.
R1	X	100K	½W	10%	172051000
R2	X	82K	½W	10%	172048200
R3	X	1500	½W	10%	172031500
R4	X	100K	½W	10%	172051000
R5	X	2200	½W	10%	172032200
R6	X	100K	½W	10%	172051000
R7	X	2200	½W	10%	172032200
R8	X	10K	½W	10%	172041000
R9	X	1500	½W	10%	172031500
R10	X	100K	½W	10%	172051000
R11	X	82K	½W	10%	172048200
R12	X	100K	½W	10%	172051000
R13	X	2200	½W	10%	172032200
R14	X	100K	½W	10%	172051000
R15	X	82K	½W	10%	172048200
R16	X	100K	½W	10%	172051000
R17	X	2200	½W	10%	172032200
R18	X	100K	½W	10%	172051000
R19	X	2200	½W	10%	172032200
R20	X	10K	½W	10%	172041000
R21	X	1500	½W	10%	172031500
R22	X	100K	½W	10%	172051000
R23	X	82K	½W	10%	172048200
R24	X	100K	½W	10%	172051000
R25	X	2200	½W	10%	172032200
R26	X	100K	½W	10%	172051000
R27	X	2200	½W	10%	172032200
R28	X	10K	½W	10%	172041000
R29	X	1500	½W	10%	172031500
R30	X	100K	½W	10%	172051000
R31	X	82K	½W	10%	172048200
R32	X	100K	½W	10%	172051000
R33	X	2200	½W	10%	172032200
R34	X	100K	½W	10%	172051000
R35	X	82K	½W	10%	172048200
R36	X	100K	½W	10%	172051000
R37	X	2200	½W	10%	172032200
R38	X	100K	½W	10%	172051000
R39	X	2200	½W	10%	172032200
R40	X	10K	½W	10%	172041000
R41	X	1500	½W	10%	172031500
R42	X	100K	½W	10%	172051000
R43	X	82K	½W	10%	172048200
R44	X	2200	½W	10%	172032200
R45	X	100K	½W	10%	172051000
R46	X	100K	½W	10%	172051000
R47	X	82K	½W	10%	172048200
R48	X	100K	½W	10%	172051000
R49	X	2200	½W	10%	172032200
R51	X	5600	½W	10%	172035600
R52	X	10K	½W	10%	172041000
R53	X	100K	½W	10%	172051000
R54	X	10K	½W	10%	172041000
R55	X	1500	½W	10%	172031500
R56	X	100K	½W	10%	172051000
R57	X	10K	½W	10%	172041000
R58	X	1500	½W	10%	172031500
R59	X	100K	½W	10%	172051000
R60	X	10K	½W	10%	172041000
R61	X	1500	½W	10%	172031500
R62	X	100K	½W	10%	176051000
R63	X	10K	½W	10%	172041000
R64	X	1500	½W	10%	172031500
R65	X	100K	½W	10%	172051000
R66	X	10K	½W	10%	172041000
R67	X	1500	½W	10%	172031500
R68	X	100K	½W	10%	172051000
R69	X	10K	½W	10%	172041000
R70	X	1500	½W	10%	172031500
R71	X	1500	½W	10%	172031500
R72	X	1000	½W	10%	172031000
R73	X	1000	½W	10%	172031000
R74	X	1000	½W	10%	172031000
R75 to R80	X	1500	½W	10%	172031500

VT1	D1561		300552991
VT2	D2039		300553421
VT3 to VT5	D1561		300552991
VT6	D2039		300553421
VT7	D1561		300552991
VT8	D2039		300553421
VT9 to VT11	D1561		300552991
VT12	D2039		300553421
VT13 to VT15	D1561		300552991
VT16	D2039		300553421
VT17	D1561		300552991
VT18	D2039		300553421
VT19 to VT21	D1561		300552991
VT22	D2039		300553421
VT23 to VT31	D1561		300552991
MR1 to MR46	SD3	Solartron	300522160





Component Location - Board 2

SOLARTRON
Schlumberger

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